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SEPTEMBER, 1929

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CORRECTION

See page 388 of this issue.

MONTHLY WEATHER REVIEW

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THE TEPHIGRAM [1]—ITS THEORY AND PRACTICAL USE IN WEATHER FORECASTING

By CLIFFORD M. ALVORD AND ROBERT HALL SMITH

SYNOPSIS I. DESCRIPTION AND USE OF TEPHIGRAMS; II. GENERAL DISCUSSION; III. INDIVIDUAL DISCUSSION OF KITE ASCENTS; IV. CONCLUSIONS; V. TEPHIGRAMS

DESCRIPTION AND USE OF THE TEPHIGRAM

For a number of years it has been felt necessary to develop a method of plotting meteorological data on a thermodynamical basis. The common method of portraying the physical state of the atmosphere by plotting temperature or pressure against height is not very well suited for scientific thermodynamical discussions.

As early as 1884 Hertz gave a graphical method for the determination of the adiabatic changes of state of moist air. He used a double series of adiabatic lines, one series for saturated air, the other for unsaturated or dry air, to trace the behavior of air containing any given amount of water vapor. Neuhoff, a little later, elaborated on the method of Hertz and introduced an adiabatic chart which is now called the Neuhoff diagram. This diagram consists of a ground work of adiabatic lines for dry air and reversible adiabatics for saturated air, referred to temperature and the logarithm of pressure as coordinates.

Sir Napier Shaw has long studied the thermodynamical properties of the atmosphere. He was one of the first to see the advantages of the Hertz and Neuhoff diagrams. He carried his investigations still further. While on a Neuhoff diagram it may be ascertained whether the atmosphere on any specific occasion as defined by the observations from an airplane flight or registering balloon is in stable equilibrium or not, there is no means by which an estimate may be made as to the consequences which will result from the departure from the conditions of equilibrium. To make such an estimate possible it is necessary to have a diagram with coordinates by which energy can be represented. From these considerations Shaw finally devised a method of plotting upper-air data in the form of a curve, which he has called the tephigram. This curve is plotted on squared paper on which the ordinates represent entropy (ϕ) or the logarithm of potential temperature (θ) and the abscissæ absolute temperature (T). Total entropy of moist air includes the entropy of dry air and also that of the water vapor. On this diagram dry air alone is regarded as the working substance and any moisture carried along is regarded as a reservoir of latent energy which is realized when condensation takes place, all other effects of water vapor are neglected. Only this realized entropy is shown; loss of water and the latent heat of condensation are compensated for by increasing the realized entropy of the dry air.

With the above coordinate system, any area measured represents work, or $\int T d\phi$. By means of a planimeter this area can be measured and its actual numerical value in energy units computed. Since entropy, ϕ, is proportional to the logarithm of potential temperature, θ

$$\phi = C_p \log \theta + K,$$

Shaw found it more convenient to work directly with entropy. Entropy is found from the equation

$$\phi = C_p \log \frac{T}{T_0} - \frac{\mathrm{R}}{\mathrm{m}} \log \frac{p}{p_0} = C_p \log \frac{T}{100} - \frac{\gamma - 1}{\gamma} C_p \log \frac{p}{1{,}000},$$

the entropy being measured with reference to the point $T_0 = 100°$ C. *A.*, $p_0 = 1{,}000$ millibars.

From the last equation Shaw has computed tables for the entropy using the following constants:

$$C_p = 0.2417 \times 4.18 \times (10)^7 \text{ c. g. s. units}$$
$$\gamma = 1.40.$$

By using the temperature in C° and pressure in millibars as given by the recording instruments, the entropy can be conveniently and rapidly found.

Below is a brief description of a temperature-entropy diagram (fig. 1) with a short résumé of the equations from which the various lines shown on the diagram may be computed. Horizontal lines, being lines of constant entropy and constant potential temperature, are dry adiabatics. Vertical lines are isotherms. The lines of equal pressure slope downward to the right and can be computed from the equation of entropy,

$$\phi = C_p \log \frac{T}{T_0} - \frac{\mathrm{R}}{\mathrm{m}} \log \frac{p}{p_0},$$

where T_0 is equal to 100° C. and p_0 is 1,000 millibars. The saturated or irreversible adiabatics curve upward to the right, gradually becoming parallel to the dry adiabatics in the lower pressure regions. These lines are computed from the equation

$$C_p \log T - \frac{\mathrm{R}}{\mathrm{m}} \log p + 0.622 \frac{re}{pT} = K,$$

which is similar in form to Poisson's equation with an addition to take care of the water-vapor content. These lines are really the so-called pseudo adiabatic lines in contradistinction to the true or reversible adiabatics. That is, the water vapor is condensed and falls out as a mass of air is cooled, and the amount precipitated can be actually determined by means of the water-vapor content or so-called saturation lines. The dotted lines, nearly perpendicular to the isobars are lines showing the number of grams of water vapor which will saturate 1 kilogram of dry air. These lines are drawn from the equation

$$q = \epsilon \frac{e_m}{b - e_m(1 - \epsilon)} \quad (q = \text{specific humidity})$$

[1] Submitted in partial fulfillment of the requirement for the degree of master of science from the Massachusetts Institute of Technology, 1929. First published in Professional Notes of the Meteorological Course of the Massachusetts Institute of Technology. This explains why the numbers of the figures do not run consecutively.

in which ϵ is the specific gravity of water vapor with reference to dry air and is taken as 0.622, e_m saturation water vapor pressure, b the barometric pressure. The amount of water which has been condensed and precipitated can be ascertained by noting the differences between the index of the saturation line through the point at which saturation was reached and that of the saturation line through the final position of the tracing point.

A tephigram as previously defined is the curve plotted on the temperature entropy diagram showing the actual observed conditions of the atmosphere. Once the coordinates are obtained, it is a simple procedure to plot in the curve. The interpretation of this curve is by no means difficult. If moisture did not exist in the atmosphere the plotting of upper air data and reasonably saturated air and it will be seen since the line AF is everywhere to the left of the tephigram AKCDF, the rising air will be warmer throughout than its environment. It will, therefore, have buoyancy and be capable of doing work as it rises. When the area lies above the tephigram it is called positive area and represents energy available for producing convection and instability, which in turn gives rise to thunderstorms and other weather disturbances. An area below the tephigram, as AKB, is called negative area and represents stability, since spontaneous ascent of the air in this case is not possible. An explanation of this area will be given later on.

Spontaneous ascent of saturated air can occur only in regions where the saturation adiabatic through the starting point keeps on the warm side of—that is, above—the

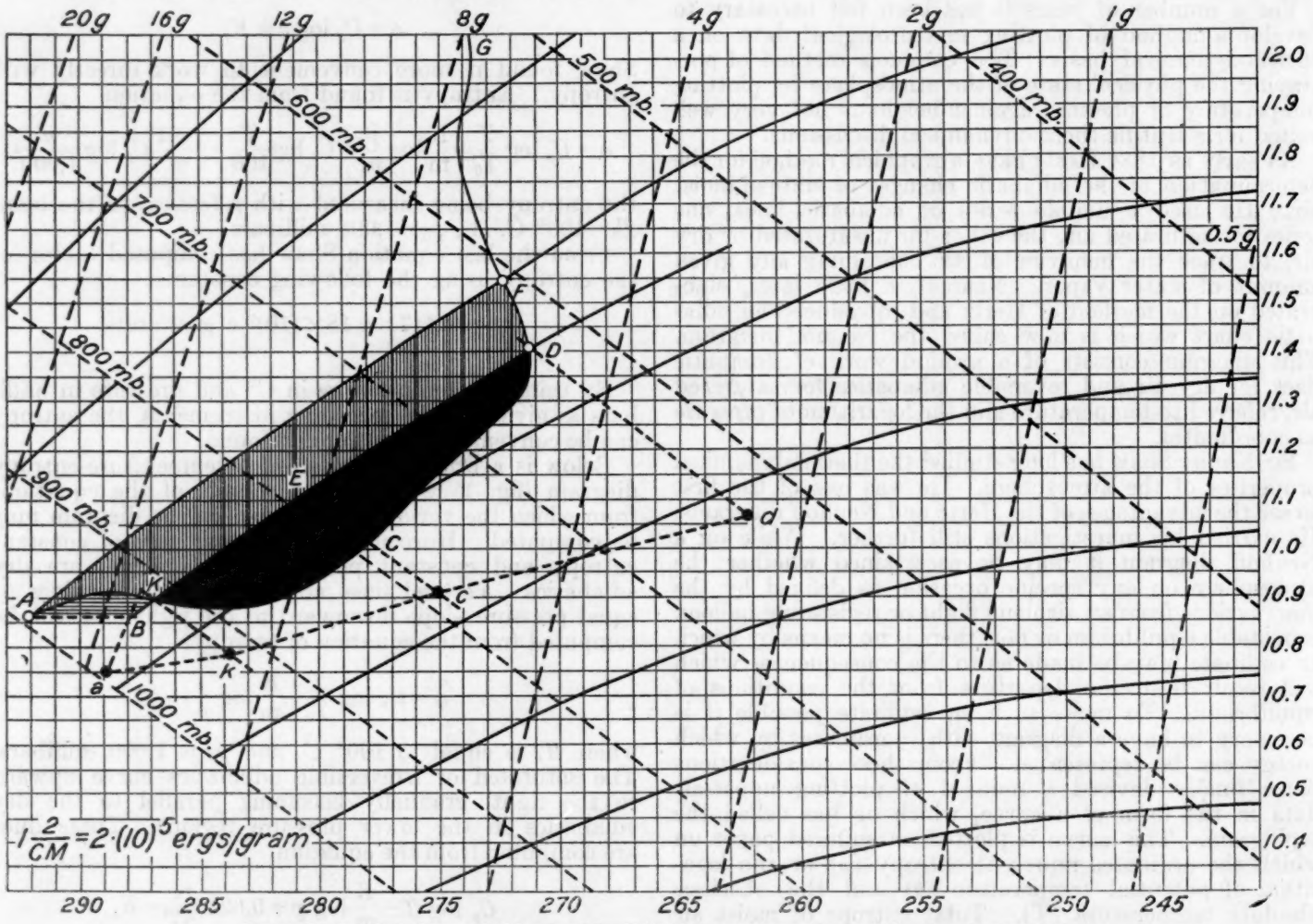

FIGURE 1.—Sample tephigram; for the sake of simplicity the temperature and entropy lines have been omitted

correct deductions therefrom would be quite simple. But moisture is as important as lapse rate in all considerations of stability. Therefore, it is necessary to indicate the water content of the air if the diagrams are to be of any practical value. This is done by plotting a curve of dew points in connection with the tephigram.

To illustrate the foregoing, a sample tephigram is shown on Figure 1. The changes of temperature and entropy from the surface to the highest point reached in the troposphere are shown by the curve AKCDFG, the tephigram. If the air at the point marked A were saturated, the energy which would be liberated as one kilogram of air rose pseudo-adiabatically from A to F is indicated by the whole area shaded on the diagram. The upper boundary of the area is an adiabatic line for tephigram. This implies instability for saturated air. A deviation of the tephigram upward from the saturated adiabatic indicates stability for saturated air. Spontaneous ascent of dry air can occur only in regions where the graph of the sounding slopes downward from the horizontal, implying instability for dry air, that is, a super adiabatic lapse rate. Stability is indicated by a deviation of the tephigram upward from the horizontal. Temperature inversions are shown by deviation of the tephigram to the left of the vertical, and isothermal regions by no deviation from the vertical.

The method of plotting humidities is to plot the dew points as well as the air temperature on each pressure line. On the diagram (fig. 1) "A" shows the temperature 292° at 990 millibars pressure and "a" the dew

point 289° C. A. at the same pressure. After having compared several diagrams, the length of the line Aa gives an indication of the dryness of the air. This method shows the variations of humidity throughout an ascent, but it does not appear suitable for the study of the energy available in a mass of air rising from a particular layer. Such a curve of dew points is called a depegram, and on the figure it is represented by the dotted line "akcd."

Mr. J. S. Dines has put forth an alternative plan; that is, to calculate the weight of water vapor per kilogram of dry air present at the level, A. Through A draw a horizontal line to B. This point B marks the temperature at which this calculated weight of water vapor is the saturated content of the air. The water vapor content lines on the diagram make the plotting of the point B easy. Actually, the above process simply illustrates the path of a moving particle of air. It starts from some level where it is not saturated, rises along the dry adiabatic until it becomes saturated (at B), and from there continues along the wet adiabatic; that is, in the rain stage. (Sir Napier Shaw has pointed out that in the application of thermo-dynamics to practical meteorology the snow and hail stages may be omitted.) During the first stage ABK, the air will be colder than its surroundings and work will have to be done on the particle to raise it (negative area). During its course along KED it will be warmer than its surroundings, rise of its own accord, and will do work, liberate energy, as indicated by the double hatched area on Figure 1. This area then is the measure of the available energy. By this method of plotting, instability of the atmosphere may be studied. It makes it plain where large quantities of energy would be available if the air were saturated, whereas in conditions actually existing due to the fact that the air is not completely saturated, the available energy is greatly reduced, often becoming negative.

The area bounded by the tephigram and the adiabatic followed is a measure of the convective energy that can be made available through a displacement of the kilogram of air considered. In the accompanying graphs positive areas are shaded red, negative areas, blue.[2]

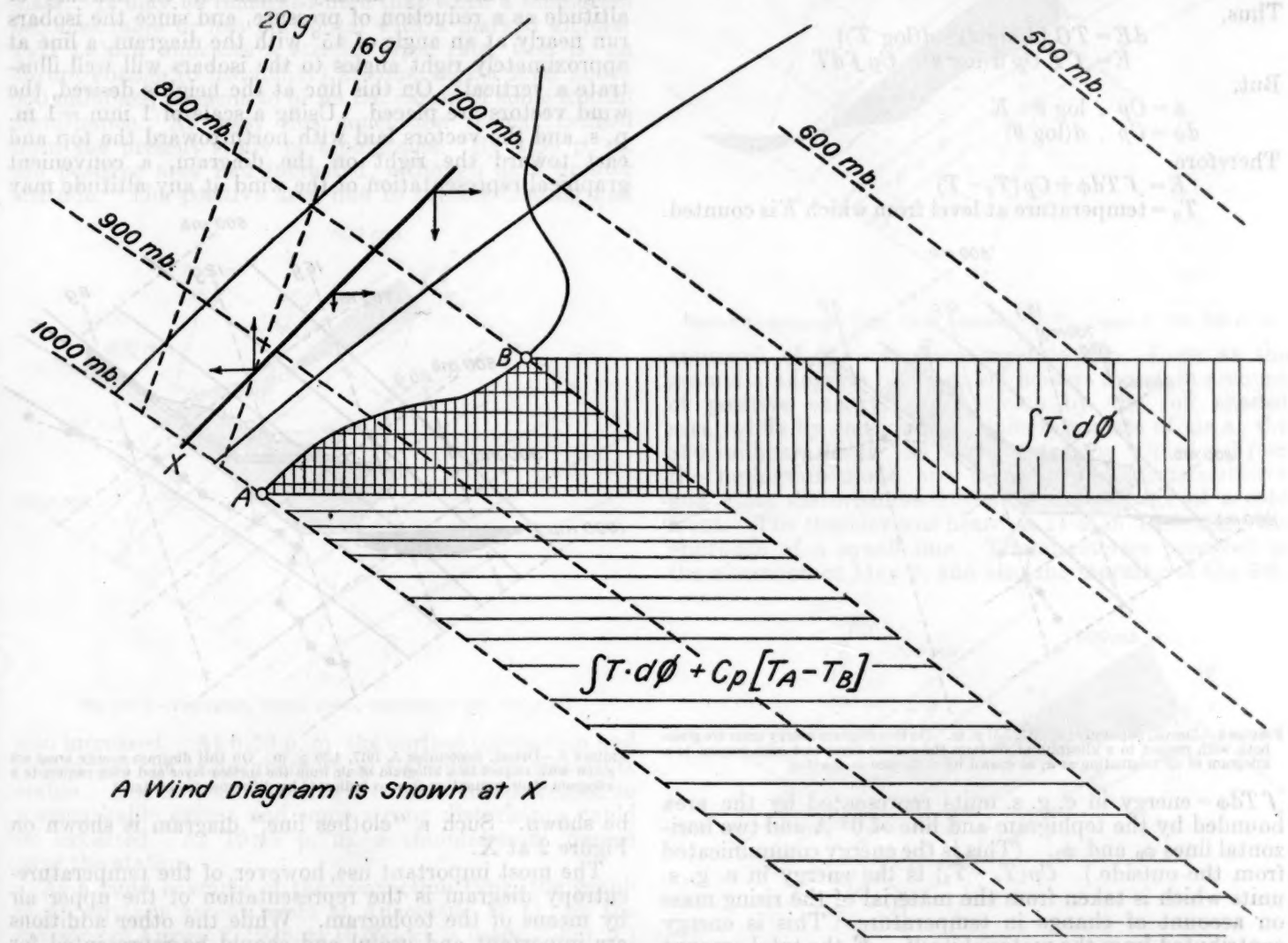

FIGURE 2.—Computation of height by means of the tephigram. The horizontal shaded area extended to absolute zero by the continuation of the 800 and 1,000 millibars isobars represents the change of geopotential from A to B. The area vertically hatched, extending from the $T\phi$ gram, A–B, to absolute zero, is a measure of $\int T.\, d\phi$

Height can also be computed by means of the ϕT–diagram as shown by Sir Napier Shaw in the following manner. The geopotential of a particle, from which the altitude is easily derived, is the energy required to lift it against gravity to its position. Therefore the problem is simply that of finding the value of $\int_0^z g.\, dz$.

Let E be the geopotential at any height.

[2] In order to avoid the necessity of printing in two colors the positive areas in red are printed in solid black and the negative areas in blue are shaded.

$$dE = g \cdot dz$$
$$dp = -g\rho dz$$
$$dp = -\rho dE$$
$$dE = \frac{-dp}{p} \cdot \frac{RT}{m} = \frac{-RT}{m} d(\log p)$$

From the definition of potential temperature (θ) it follows that

$$\log p_0 - \log p = \frac{mCp}{R} [\log \theta - \log T]$$

p_0 = constant standard pressure

$$-d(\log p) = \frac{mCp}{R} [d(\log \theta) - d(\log T)]$$

Thus,

$$dE = TC_p[d(\log \theta) - d(\log T)]$$
$$E = \int T.Cp\, d(\log \theta) - Cp \int dT$$

But,

$$\phi = Cp \cdot \log \theta + K$$
$$d\phi = Cp \cdot d(\log \theta)$$

Therefore

$$E = \int T d\phi + Cp(T_0 - T)$$

T_0 = temperature at level from which E is counted.

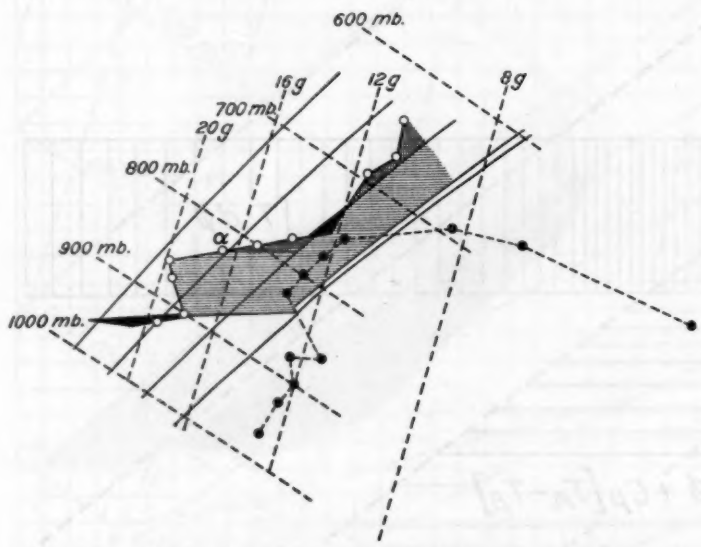

FIGURE 4.—Drexel, September 5, 1917, 2:51 p. m. On this diagram energy areas are given both with respect to a kilogram of air from the surface layer and with respect to a kilogram of air originating at α, as shown by difference in shading

$\int T d\phi$ = energy in c. g. s. units represented by the area bounded by the tephigram and line of 0° A and two horizontal lines ϕ_0 and ϕ_1. (This is the energy communicated from the outside.) $Cp(T_0 - T_1)$ is the energy in c. g. s. units which is taken from the material of the rising mass on account of change in temperature. This is energy contributed from the material itself. E, the total amount of energy involved in the process, which can also be measured on the diagram by the area bounded by the tephigram and the pressure lines through these points down to 0° A, is calculated as follows.

Consider in Figure 2 two points on the tephigram A and B. To calculate the height between these two points we first get the value of $\int T d\phi$ by measuring the area on the diagram bounded by the curve AB and vertical line through 0° A and the horizontal lines ϕ_a and ϕ_b by planimeter or counting the squares. This area equals 383 square centimeters. The diagram is so constructed that 1 square centimeter $= 2 \times 10^5$ ergs. $383 \times 2 \times 10^5 = 766 \times 10^5$ ergs = 766 geodynamic meters. To obtain the other component $C_p(T_0 - T_1)$ from A to B, we need only know the temperature difference between these two points (10.6° C.)

$1.01 \times 10^7 \times 10.6 = 10.706 \times 10^7$ ergs. $Cp = 1.01 \times 10^7$
$= 1{,}070.6$ g. d. m.

The total height = 1,070.6 + 766 = 1,836.6 geodynamic meters. To obtain height in meters Bjerknes' tables are used and for latitude 45° N. the result is 1,875 meters.

To make the diagram complete there is still to be added a means by which the velocity and direction of the wind at the various altitudes may be represented. This is done by means of what Shaw calls the "clothes line" diagram. Since we usually think of an increase of altitude as a reduction of pressure, and since the isobars run nearly at an angle of 45° with the diagram, a line at approximately right angles to the isobars will well illustrate a vertical. On this line at the heights desired, the wind vectors are placed. Using a scale of 1 mm. = 1 m. p. s. and the vectors laid with north toward the top and east toward the right on the diagram, a convenient graphical representation of the wind at any altitude may

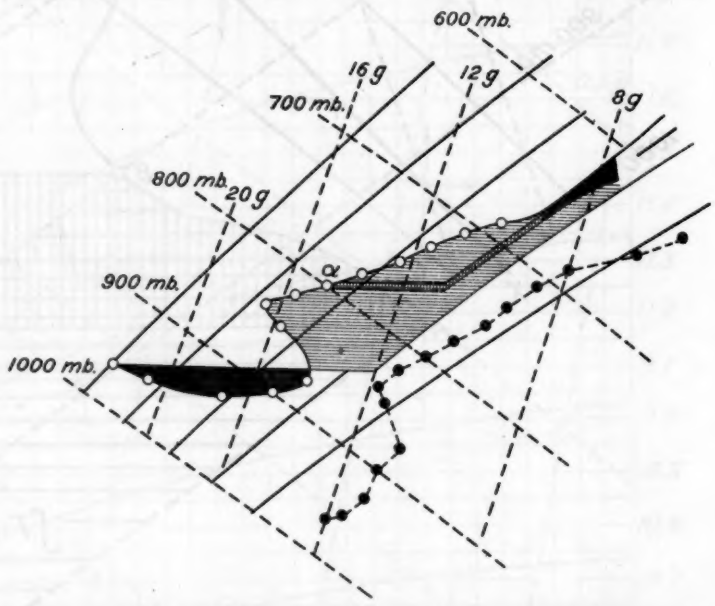

FIGURE 5.—Drexel, September 5, 1917, 4:50 p. m. On this diagram energy areas are given with respect to a kilogram of air from the surface layer and with respect to a kilogram of air originating at α, as indicated by difference in shading

be shown. Such a "clothes line" diagram is shown on Figure 2 at X.

The most important use, however, of the temperature-entropy diagram is the representation of the upper air by means of the tephigram. While the other additions are important and useful and should be represented for future use, they would take too much time to compute for immediate use. The tephigram on the other hand, can quickly and easily be made. To show that it is a valuable aid to forecasting is the purpose of the following discussion of certain weather conditions in the United States.

II. GENERAL DISCUSSION

The principal practical use to which tephigrams may be put is that of local forecasting. From a study of numerous tephigrams indicating available energy it is found that they may be divided into two broad types; (*a*) frontal type, that is those which give an indication of the approach and passage of a boundary between different air masses, and (*b*) convective type, those which show a pure convection type of disturbance within a homogeneous air mass.

These broad divisions were made by analyses of the synoptic charts in conjunction with the tephigrams for the same periods. As an example of the frontal type the series of graphs from Drexel (Nebr.) beginning with the 5th of September, 1917, 7:16 a. m. is used. (Figs. 4, 5, 6.) The morning ascent (not reproduced) shows a very stable atmosphere to great height; the depegram shows low relative humidity. By 3 p. m., as graph 4 shows, a region of conditioned instability had developed at a height of 840 millibars, with a remarkable increase in humidity. The small positive area at the surface is due to surface convection, but that at the height of 750 millibars can be due only to the bringing in of a new air mass. It may be remarked here that when a tephigram becomes more or less horizontal with a marked angular shift (which indicates a steeper lapse rate, that is, an abrupt change to instability) at some higher level above 900 millibars, it seems to be an indication of some frontal disturbance. At least this conclusion seems justified from the present study of tephigrams. By 4:50 p. m. the positive area had increased, although at a greater altitude. The positive area due to surface heating had

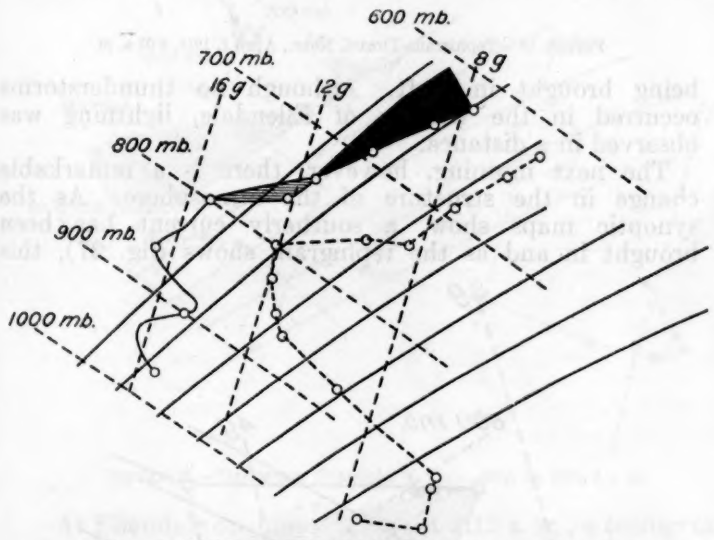

FIGURE 6.—Tephigram, Drexel, Nebr., September 5, 1917, 6:50 p. m.

also increased. At 6:50 p. m. the surface convection had ceased and the atmosphere up to 800 millibars was quite stable. But now the positive area aloft has increased to a remarkable extent and some strong disturbance could be expected. At 10:45 p. m. a thunderstorm passed over the station.

As a good example of the convection type, the graph of an airplane ascent made at Anacostia, D. C., on the morning of August 2, 1928, at 10 o'clock is used. (Fig. 9.) Here the outstanding feature is the enormous positive area extending from the surface upwards. The tephigram shows no leveling off, but is more or less a curve with a constant slope. That is, there is no abrupt change in the lapse rate. Also there is the marked superadiabatic lapse rate at the surface. The depegram follows the general form of the tephigram which is also another characteristic of this type of disturbance. A thunderstorm occurred on this day at about 4 p. m.

III. INDIVIDUAL DISCUSSION OF KITE ASCENTS

Under this heading each series of ascents will be discussed separately. First, will be taken those tephigrams which show frontal disturbance and last, those which show the convective type. Between the two is given an example which appears to be a combination of the two types.

The synoptic maps for the 7th and 8th of May, 1918 do not indicate to any great extent what the weather conditions will be in the neighborhood of Drexel. From the tephigram for the 8th of May at 8:57 a. m. (fig. 12) with the sudden change from the stable lapse rate to the very steep one above 900 millibars accompanied with increase of relative humidity, one could see the first

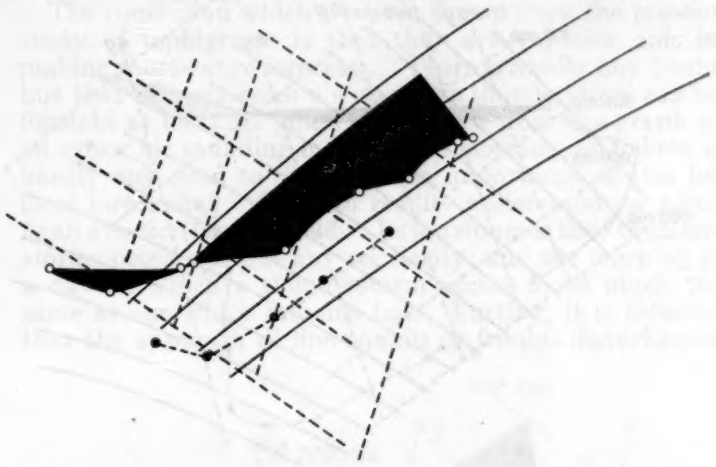

FIGURE 9.—Aerograph flight 111-28 Anacostia, D. C., August 2, 1918, 9:56 a. m.

approach of the over running cold air. Even at the ground a kilogram of air would possess a certain amount of positive energy, as is shown by the full shaded area, while by considering a kilogram mass of air at the 890 millibars level, the positive area is tripled. From the tephigram alone one could expect thunderstorms and other disturbances following the passage of a cold front. The thunder was heard at 11 a. m. indicating the approach of a squall line. Thunderstorms occurred in the afternoon of May 8, and also the morning of the 9th.

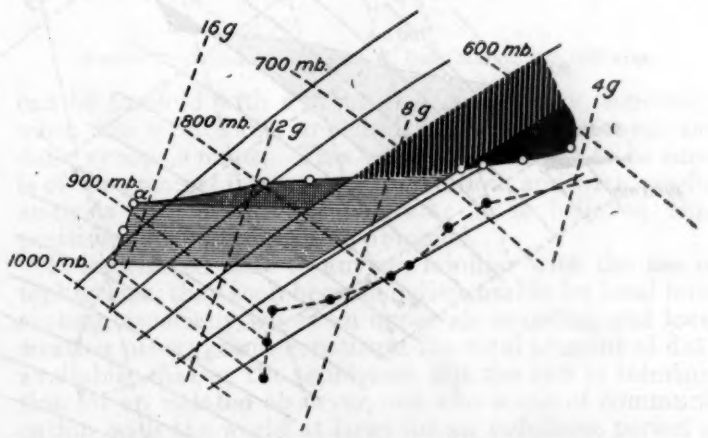

FIGURE 12.—Drexel, May 8, 1918, 8:57 a. m. On this diagram energy areas are given with respect to a kilogram of air from the surface layer and with respect to a kilogram of air originating at α

* * * * *

The graphs for Drexel on June 11 (figs. 13 and 14) are good examples of the appearance of tephigrams when cold air is brought in at higher altitudes. The graph for 6:21 a. m. shows great stability from the ground to 900 millibars. From 900 to 800 millibars the lapse rate has become steeper than that for saturated air, but the water vapor content has not increased to any great extent, and the relative humidity is still quite low. At 800 millibars, however, the air becomes very unstable, the lapse rate changes abruptly to the superadiabatic, and the relative humidity increases rapidly. This implies a different air

mass in this upper region, which is borne out by an inspection of the synoptic maps for this period. A cold front is approaching and this is an indication of overrunning cold air.

The graph for noon of that day shows a small positive area above 600 millibars. This area itself would not indicate any great disturbance, but here we must rely on our previous knowledge of weather sequence following

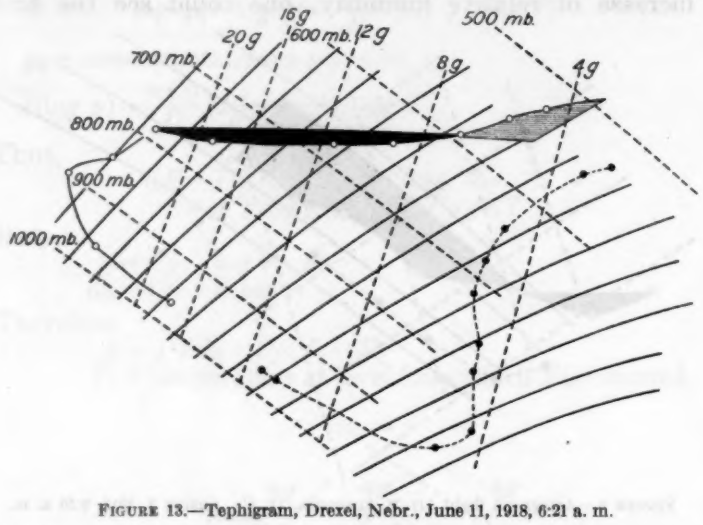

FIGURE 13.—Tephigram, Drexel, Nebr., June 11, 1918, 6:21 a. m.

such weather conditions. Thunderstorms could be safely predicted as well as cold front rains. At 6 : 23 p. m. the squall line was observed approaching.

* * * * *

The series beginning with April 1, 1918, 8 : 03 a. m. at Drexel (figs. 15 and 16), depicts the bringing in of cold air between the 1st and 2d of April. Graph 15 shows great

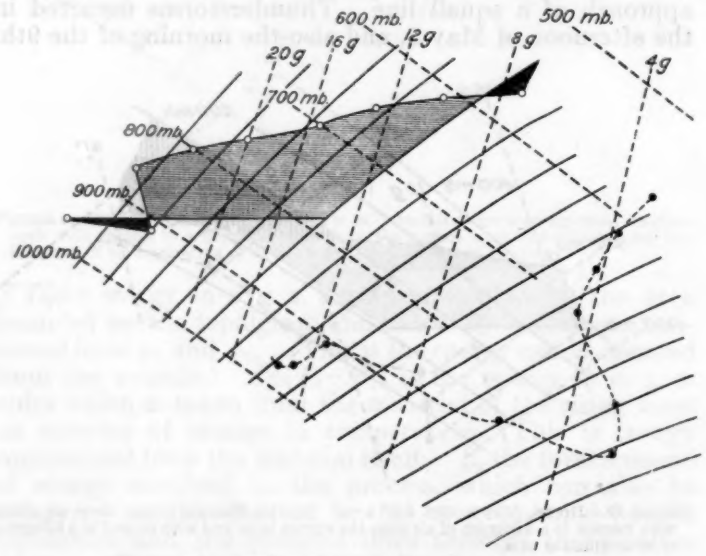

FIGURE 14.—Tephigram, Drexel, Nebr., June 11, 1918, noon

stability in a homogeneous air mass. On April 2 at noon (fig. 16), although there is a positive area at the ground, the real significant point is the superadiabatic lapse rate at 820 millibars. The curve of dew points follows in general the tephigram until 820 millibars, where the relative humidity begins to increase with altitude. From such a tephigram one could expect the weather which would occur with the approach and passage of a cold front. Rain, turning to sleet, and thunder followed shortly after this graph was taken.

* * * * *

At Ellendale on May 30, 1918, the tephigram for 9 p. m. (fig. 26) showed stability from the surface to 700 millibars. At that point there is an abrupt increase in humidity and the lapse rate becomes superadiabatic. This, as has been shown, would indicate a new air mass

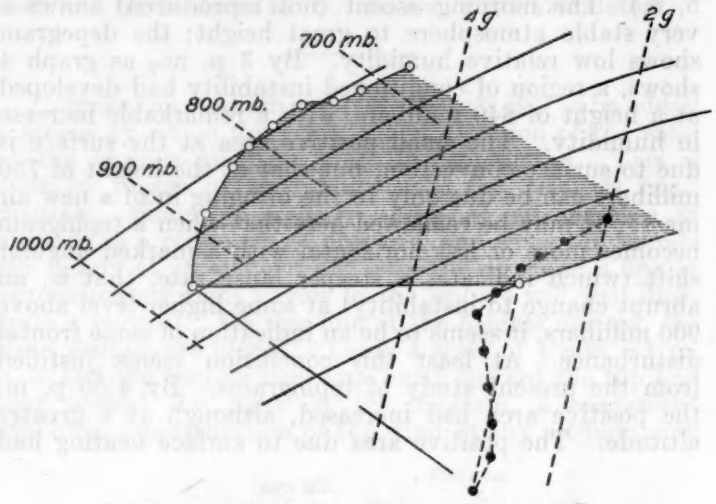

FIGURE 15.—Tephigram, Drexel, Nebr., April 1, 1918, 8:03 a. m.

being brought in aloft. Although no thunderstorms occurred in the vicinity of Ellendale, lightning was observed in a distance.

The next morning, however, there is a remarkable change in the structure of the atmosphere. As the synoptic maps show, a southerly current has been brought in and as the tephigram shows (fig. 27), this

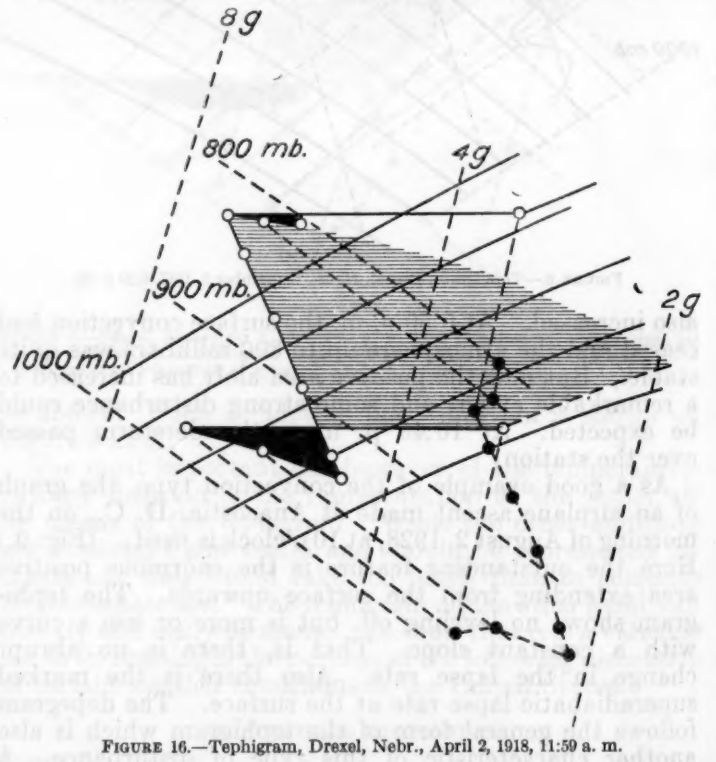

FIGURE 16.—Tephigram, Drexel, Nebr., April 2, 1918, 11:59 a. m.

mass extends from the surface to high levels. The great instability shown on this graph, May 31, 1918, is caused by convection, and the thunderstorm which could easily be forecast, occurred at 5 : 30 p. m.

This series is an example of convection coupled with the instability of a new air mass brought in giving rise to thunderstorms.

* * * * *

The tephigrams heretofore considered have been the frontal type, with one example of a transition type in which convection has played an important part. The remainder of the discussion will concern a few cases which show the instability caused solely by convection. The first one here discussed, that of Drexel (fig. 34), on August 16 at 8:25 a. m., is an excellent example. The tephigram shows a moderate amount of positive area at the surface extending up to 900 millibars. From 900 to 750 the air is stable and an area of negative energy exists. Above this there is positive energy. It is reasonable to assume on the basis of experience that a thunderstorm will occur during the afternoon. At 2:15 p. m. a tephigram shows that the negative area has been wiped out completely, so now we can expect a thunderstorm in the very near future. At 2:30 p. m. one was forming to the northwest. Since in forecasting at least a 6-hour forecast should be made, the tephigram of 2:15 p. m. (fig. 35) would not be of much use. However, in this case from Figure 34 there is hardly any doubt, as said above, but that a thunderstorm would occur in the afternoon.

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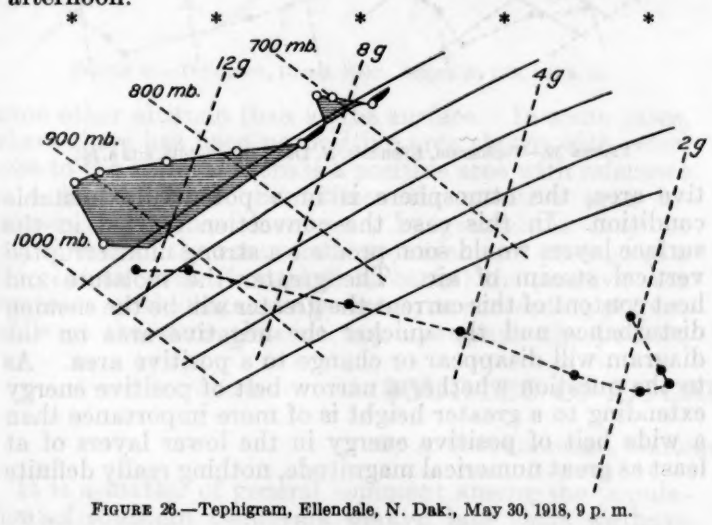

FIGURE 26.—Tephigram, Ellendale, N. Dak., May 30, 1918, 9 p. m.

At Ellendale on June 6, 1918, at 8:12 a. m., a tephigram (fig. 39) shows instability in the lower levels with a marked temperature inversion below 900 millibars. The positive area near the surface appears to be a little above normal for the time of day, but above this there is only negative area extending up to about 540 millibars showing a stable stratification at high levels. The weather remained clear all of that day and night. The following day shortly after noon a tephigram (fig. 40) has very much the same characteristics near the surface with an inversion just above 900 millibars. Above the inversion there is a small amount of positive area showing that conditions are more favorable for some form of weather disturbance. At 5 p. m. the same afternoon, there was thunder and lightning to the south of the station, and the next day there was a thunderstorm at the station itself.

* * * * *

On August 20, 1918, at 1:05 p. m. at Drexel, a tephigram shows a normal moderate amount of positive area in lower levels with instability due to surface heating. From 850 to 750 millibars the air became stable, giving a negative area for this region. Above is positive energy extending to the top of the curve. Conditions appear to be favorable for thunderstorms sometime later in the afternoon or night. A tephigram (fig. 46), plotted from data taken the next morning, shows positive area at the surface and at high levels, with negative area in between, and a marked inversion from 920 to 880 millibars. At 3:55 p. m. that afternoon a tephigram (fig. 47) shows that the inversion has been wiped out through increased surface convection and the negative area greatly reduced. From this we can assume that conditions are favorable for a thunderstorm in a few hours. About 6 p. m. one occurred 8 miles away.

IV. CONCLUSIONS

The conclusion which we have drawn from the present study of tephigrams is that they are valuable aids in making short-range forecasts. There is hardly any doubt but that in most cases a convection thunderstorm can be foretold at least six hours in advance from the graph of an upper air sounding made in the morning, and there is hardly any need to dwell on the importance of this for local forecasting. One can readily understand its value to an aviation landing field. In the summer time thunderstorms occur without any regularity, and the morning of a day on which a thunderstorm occurs looks much the same as one which remains fair. Further, it is believed that the approach of line squalls or frontal disturbances

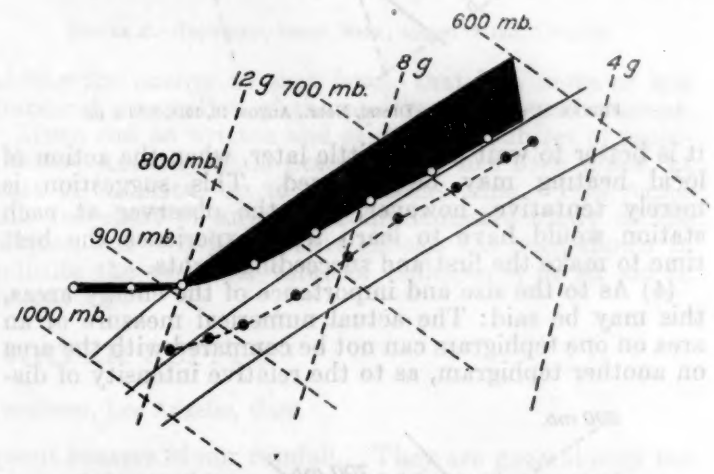

FIGURE 27.—Tephigram, Ellendale, N. Dak., May 31, 1918, 11:08 a. m.

can be foretold with a great deal of accuracy, especially when the tephigrams are used in conjunction with the daily synoptic maps. This latter information, to be sure, is of the greatest importance to aviation, and with careful analysis of successive tephigrams it is believed that positive information can be obtained.

It is believed that to anyone familiar with the use of tephigrams, they soon become indispensable for local forecasting, especially where an upper air sounding and local weather observations constitute the total amount of data available; that is, the tephigram fills the gap in information for an isolated observer, one who is out of communication with the world at large for an indefinite period of time.

Certain rules seem to be brought out by the present study of tephigrams. They will be briefly stated below.

(1) It is easily seen that a small error in the relative humidity will make a large error in the amount of energy available (positive energy). This would indicate that the hygrograph used must be reliable and carefully calibrated.

(2) The other rules apply to the tephigram itself. For instance, it is not safe to extrapolate a tephigram. If the sounding has not reached a sufficient altitude, it is of little or no value. An altitude of 15,000 feet or above 700 millibars of pressure at least ought to be obtained, and this would seem to make the use of airplane ascents

imperative. The present study convinced the authors that kite ascents are of little value since a sufficient altitude is very seldom reached.

(3) The best time to make a flight or sounding is 8:30 a. m. or later (local mean time). This conclusion was reached after a comparison of the tephigrams. Before 8:30 a. m. the tephigrams do not have any individual characteristics; all are a great deal alike. In other words,

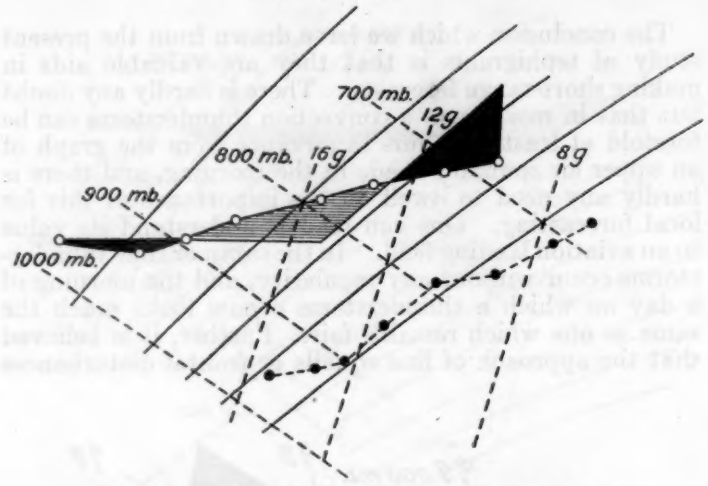

FIGURE 34.—Tephigram, Drexel, Nebr., August 16, 1918, 8:52 a. m.

it is better to wait until a little later, when the action of local heating may be observed. This suggestion is merely tentative, however, and the observer at each station would have to learn from experience the best time to make the first and succeeding flights.

(4) As to the size and importance of the energy areas, this may be said: The actual numerical measure of an area on one tephigram can not be compared with the area on another tephigram, as to the relative intensity of dis-

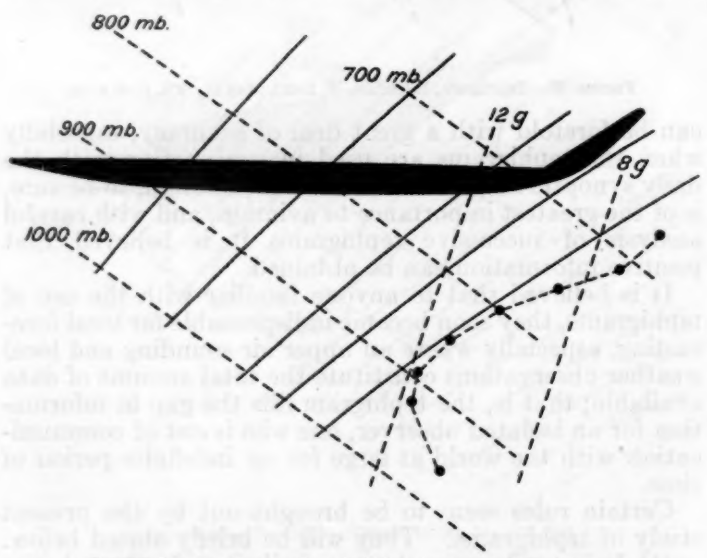

FIGURE 35.—Tephigram, Drexel, Nebr., August 16, 1918, 2:15 p. m.

turbances produced unless the tephigrams are in succession. A comparison of consecutive areas gives a better result.

For example, when a negative area is being reduced on succeeding graphs it is of as great importance as when a positive area increases. Also the relative size of positive and negative areas on the same $t-\phi$ diagram is very important. A small positive area at the surface, below a large negative area, indicates stability. The reason for this is that the small amount of instability in the surface layers is due only to the surface heating and extends only through the first few hundred meters. The large negative area is an indication of the great stability of the higher layers of the atmosphere, and for weather disturbances to be produced the effect of local heating (convection) would have to destroy the stability of the upper layers; that is, wipe out the negative area. On the other hand, when a large positive area is near the surface and a small negative area separates it from a still higher posi-

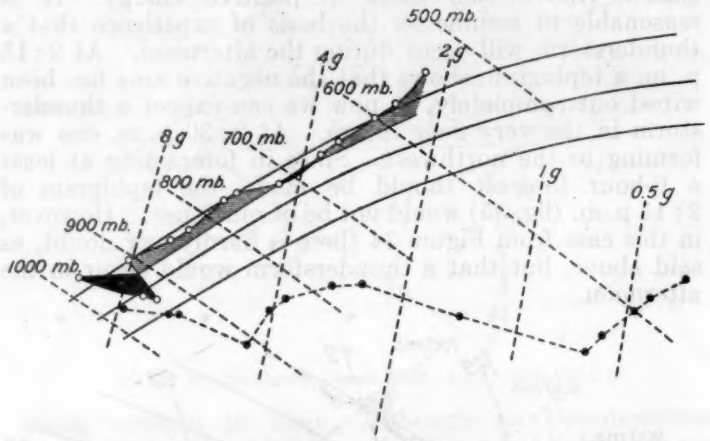

FIGURE 39.—Tephigram, Ellendale, N. Dak., June 6, 1918, 8:12 a. m.

tive area, the atmosphere is in a potentially unstable condition. In this case the convection started in the surface layers would soon produce a strong uninterrupted vertical stream of air. The greater the moisture and heat content of this current the greater will be the ensuing disturbance and the quicker the negative area on the diagram will disappear or change to a positive area. As to the question whether a narrow belt of positive energy extending to a greater height is of more importance than a wide belt of positive energy in the lower layers of at least as great numerical magnitude, nothing really definite

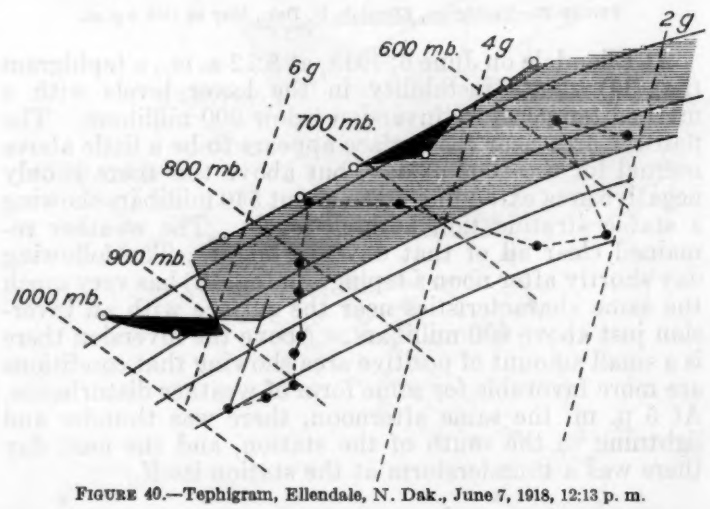

FIGURE 40.—Tephigram, Ellendale, N. Dak., June 7, 1918, 12:13 p. m.

has been proved. From the few comparisons which can be made from the present study, it would appear that the narrow belt indicates more a frontal disturbance, with a greater release of energy, while the lower wider belt of energy is of the convective type. In the discussion under the heading of "frontal type of tephigrams," the important characteristics of this type have been brought out. It is important to notice that on a frontal type of tephigram an invasion of a new air mass is indicated more by the change of the temperature lapse rate and humidity

than by the appearance of positive energy areas. The graph strikingly portrays this by the change of the slope of the tephigram and depegram. However, if with the approach of a new air mass no positive energy appears, it seems to indicate that there will be no violent thunderstorms in the neighborhood of the station itself.

(5) In some cases we have indicated positive and negative areas with reference to a unit mass of air taken at some other altitude than at the surface. In some cases, where there has been no positive area shown with reference to the surface, there is a positive area with reference to a higher point. Sometimes the positive area increases, sometimes decreases. In general, it may be stated that in the case of the approach and passage of a different air mass (frontal disturbance) the positive area increases, or the negative decreases, on succeeding graphs, while at the same time on any one graph the positive area seems to increase as the reference level of energy available is shifted upward. While it is true also of the convection type that succeeding graphs will show a gradual increase of positive area, the positive area on a single graph appears to decrease as the starting or reference point is moved upward. Theoretically, the total energy present in a certain layer could be found by adding the energy at each level, that is a more or less graphical integration of the positive and negative areas.

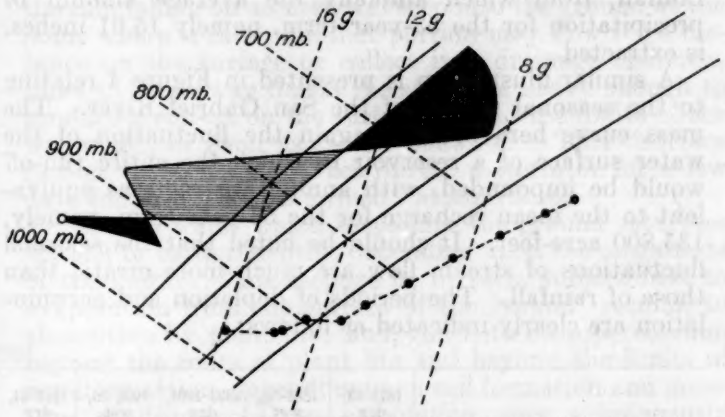

FIGURE 46.—Tephigram, Drexel, Nebr., August 21, 1918, 8:49 a. m.

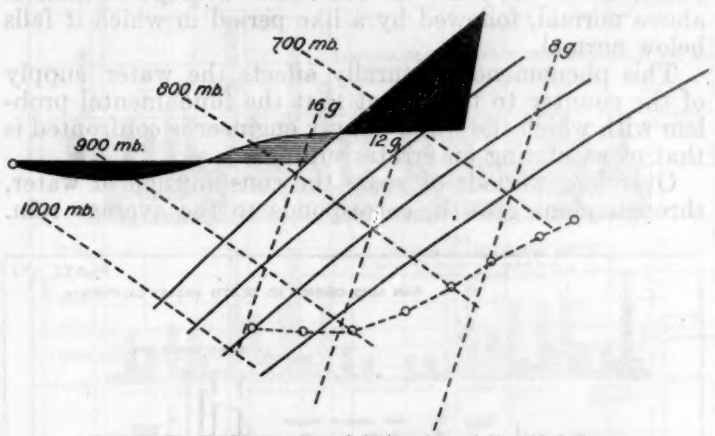

FIGURE 47.—Tephigram, Drexel, Nebr., August 21, 1918, 3:55 p. m.

Much can be written and said on the subject of tephigrams. Actually little practical use has been made, at least in America, up to the present time. This paper falls far short of any real comprehensive study of the subject, but it is hoped that enough has been shown to indicate the practical value of tephigrams as an aid in forecasting.

SOURCES OF LOCAL WATER SUPPLY [1]

By A. SONDERLEGGER, consulting engineer, Los Angeles, Calif.

It is a matter of general comment among the population of southern California that of late years we have passed through a period of drought. We have had one dry year after another; in fact, since the great floods of 1914 and 1916, we have had only three years of abnormal rainfall, while the other 10 years have been dry. Yet, we keep on pumping cheerfully from seemingly unlimited underground sources and nobody appears to worry very much except the superintendent of the water works.

The assertion is sometimes advanced that there are mysterious underground streams, or rivers, which convey water from the Mojave Desert to the Coastal Plain, or from as far distant sources as the Colorado River. There are no indications, or facts, in support of any such contentions. The mountain ranges which separate us from the desert are plutonic in origin. They are many miles in thickness and there are no passages or cavities to permit either a flow or a percolation of water across them.

Rainfall.—The water supply of any region in southern California depends entirely upon the rain falling on its contributory watershed and a study of rainfall phenomena will, therefore, disclose the basic factors affecting our water supply.

Rainstorms.—The major storms which drift from the Pacific Ocean over southern and central California are the result of areas of low barometer, usually moving from northwest to southeast. These storms are the most frequent bearers of our rainfall. They are general over the whole region and, as a rule, of fairly uniform relative intensity. The records of seasonal precipitation of any station thus are an index for a broad area.

Effect of altitude on rainfall.—The moisture-laden storm winds strike the coast from the southeast, south, and southwest. On encountering the mountains along the coast and in the interior they are forced to rise to higher altitudes, where they are cooled and precipitate a larger portion of their moisture. Thus with increasing altitude we find correspondingly larger precipitation up to about 6,000 feet, above which there is a slight decrease. This process of absorption of moisture is so effective that after passing the succession of ranges which parallel the coast there is little moisture left beyond the High Sierras, and the country to the east thereof is naturally barren. This phenomenon is illustrated on Plate 1, which represents a profile transverse to the major axis of the State, from the coast of San Luis Obispo easterly across the Santa Lucia Range to the San Joaquin Valley and thence over the High Sierras to Owens Valley and Death Valley. This is also illustrated on the same plate by a profile from the coast at Long Beach across the southern Coastal Plain and San Gabriel Valley, passing Mount Wilson of the Sierra Madre Range and on down to Palmdale in the Mojave Desert.

Rainfall cycles.—The rainfall of southern California is characterized by extreme irregularity not only from day to day or month to month of a rainy season, but also

[1] A collection of papers presented before the school of citizenship and public administration, University of Southern California, June 17–21, 1929.

from year to year. Yet, while there is an apparent irregularity of seasonal rainfall, it has nevertheless been established that within broad limits the fluctuations over long periods of years follow fairly well-defined laws, it being apparent that there are periods of wet years followed by dry periods. The duration of a complete cycle, consisting of a wet and a dry period, is 20 to 24 years, 10 to 12 years in which the average rainfall is above normal, followed by a like period in which it falls below normal.

This phenomenon naturally affects the water supply of the country to the extent that the fundamental problem with which the water-supply engineer is confronted is that of regulating an erratic supply.

Over long periods of years the consumption of water, through plant growth, corresponds to the average rain.

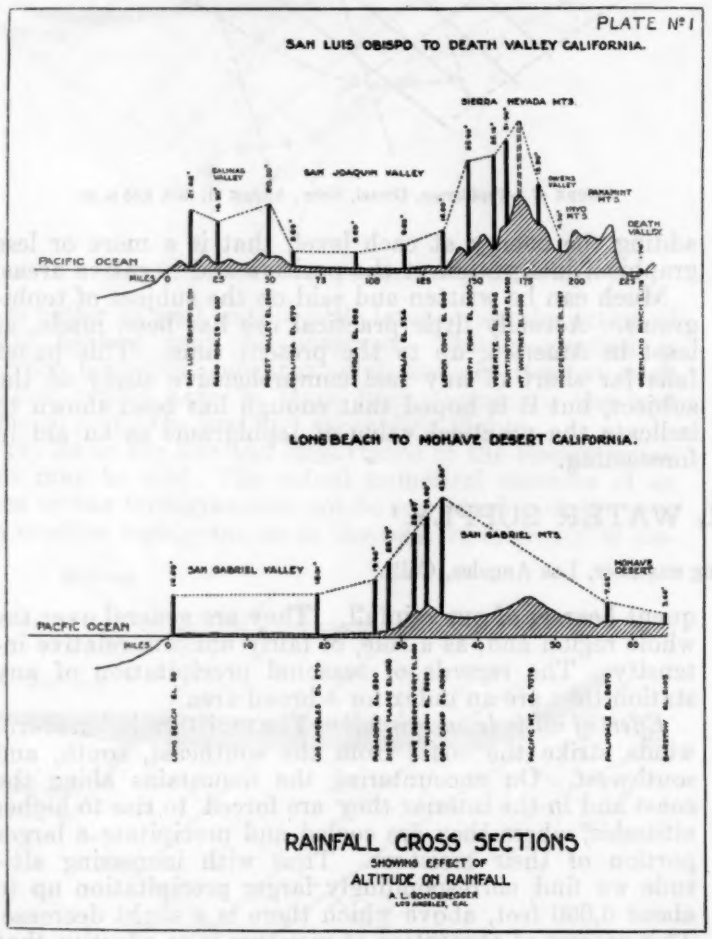

PLATE I.—Rainfall cross sections

During a series of wet years, with precipitation above normal, there will therefore be an accumulation of the surplus water reflected in heavier and deeper saturation of soils, larger stream flow, and rising ground-water levels. An occasional dry year in a wet period will only temporarily check the increase. On the other hand, a dry period will cause the gradual depletion of the water supply. This phenomenon is illustrated in Plate 2, Figures 1 and 2, which graphically show the seasonal rainfall at Los Angeles and the run-off of the San Gabriel River at Azusa for the years 1871 to 1924.

Figure 3 of the same plate shows the mass diagram, sometimes called "residual mass curve," of the rainfall for Los Angeles, platted so as to show the accumulative effect of the departure from the normal rainfall for the 53-year term. A rising line indicates a rainfall for a season above normal and a falling line a shortage. The general downward slope of the dash-and-dotted line denotes shortage over a period of years and consequently a gradual draft on the accumulated water supply, while ascent of the dash-and-dotted line indicates gradual storage of the surplus.

The mass curve then represents what would be the fluctuation of the water level in a tank exposed to the rainfall, from which annually the average amount of precipitation for the 53-year term, namely 15.01 inches, is extracted.

A similar illustration is presented in Figure 4 relating to the seasonal run-off of the San Gabriel River. The mass curve here presents again the fluctuation of the water surface of a reservoir in which the entire run-off would be impounded, with annual abstractions equivalent to the mean recharge for the 53-year term, namely, 135,800 acre-feet. It should be noted that the seasonal fluctuations of stream flow are much more erratic than those of rainfall. The periods of depletion and accumulation are clearly indicated as follows:

	1871–83, dry	1883–93, wet	1893–1904, dry	1904–16, wet	1916–24, dry
Average seasonal rainfall at Los Angeles.....inches..	13.83	20.32	11.25	16.90	12.47
Average seasonal runoff, San Gabriel River.....acre-feet..	97,258	224,470	52,427	187,492	120,162
53-year mean San Gabriel River, (135,800 acre-feet 100 per cent) .....per cent..	72	165	39	138	89

The run-off or water supply produced by the San Gabriel River in the driest period of record, 1893–1904, was only 28 per cent of the succeeding wet period. For these two periods, stream gagings exist for a sufficient number of years to make the results reliable. In order to equalize a water supply like that of the period from 1883 to 1904 to an average of 135,800 acre-feet per annum, storage capacity of nearly 1,000,000 acre-feet would have to be available, or about four times the capacity of the proposed San Gabriel Reservoir.

Figure 5, Plate 2, shows the fluctuations of a well at Baldwin Park in San Gabriel Valley for each year. The well responds to the variations in stream flow and rainfall. The ground-water basin of the San Gabriel Valley is therefore comparable to the tank above mentioned, and as a matter of fact operates as such. During a wet period this basin gradually fills with seepage water, both from the stream beds which traverse the valley and from direct percolation of rainfall, so that the water levels in wells keep on rising until this tide turns and the dry period sets in. Inasmuch as it is the function of a reservoir to be drawn down during dry years and to be replenished in wet ones, the lowering of the water table, as a result of years of drought, does not indicate or prove that the basin is overdrawn. The criterion of an overdraft is the nonreturn to original levels at the end of a wet period.

The diagrams of Plate 2 show the cyclic fluctuations as determined by observations of rainfall, stream-flow and ground-water levels. In southern California the water crop of dry periods is supplemented by cyclic underground storage. Dry years are particularly critical for the water users relying upon surface flow. The water supply must be gaged by the dry years' crop, and storage is required to regulate the excess flow of wet years. The development of a country based upon the supply of wet periods will sooner or later lead to economic disaster. The present status of the science of astronomy and the related science of meteorology does not permit of periodical

weather forecasts. Predictions as to our future water supply therefore must be based entirely upon records of past performance. Under such conditions, the records of the driest period available, combined with the possibilities of cyclic storage, must be taken into consideration in estimating the available supply, particularly where domestic supply is concerned.

Disposal of rainfall.—Generally speaking, a portion of the rain falling on an area will seep into the ground at the point where it falls; another portion may flow for a distance on the surface or collect into drainage channels, there to seep away unless the storm be heavy enough to produce a run-off on the surface beyond the limits of the watershed, or even as far as tidewater. This "surface run-off," which takes place during a storm or for a few days following, is also termed "storm run-off."

The rain water which seeps into the ground saturates the soil to various depths, depending upon the magnitude of the storm. This seepage is, in turn, subject first to evaporation from the surface of the ground; second, to absorption by plant life; and, third, to deep percolation beyond the roots of plant life and beyond the limits of capillary action, depending upon soil formation and moisture conditions. Deep percolation may subsequently drain into gullies and creeks and thus form the normal flow of a stream which occurs between storms and with perennial streams also during the summer. The normal flow of a stream is therefore a seepage run-off, seeping into the ground first and thence draining therefrom.

The evaporation and transpiration losses are generally called the "consumptive use," which is essentially a function of the character and type of soil and the soil cover.

Rainfall is therefore disposed of as "consumptive use," "seepage run-off," and "storm run-off."

This disposal of rain water takes place on the valley floor as well as in the mountains, and both types of watersheds share in the production of our water supply.

The relative effect of rainstorms of various intensities leads to the conclusion that the largest contributions to our water supply are produced by storms of great intensity, which last over several days and produce valley rains of 8 to 12 inches for the storm. Such storms produce a large storm run-off from our mountains. On the other hand, in the valley they are the cause of the deep percolation which recharges the ground-water basins. A study of the effect of individual storms on stream flow and on the fluctuations of the ground-water table, will be found to be very instructive. As a rule, a wet winter will produce one storm of outstanding intensity, which is responsible for the greater portion of the water crop of the season.

Mountain run-off.—On a mountain watershed with residual soil cover seepage water may strike bedrock at a depth of 1 to 12 feet or more, there to be diverted downhill (see figs. 3 and 4 of plate 3). On its downhill course this percolating water has to run the gantlet of absorption by the roots of trees, brush, and herbs which may have penetrated fissues to depths of 20 to 30 feet. Abstraction therefore is extremely active until the percolating water reaches the stream bed. Despite this continued tapping, however, seepage run-off is produced in dry years, although this may, in part, be due to overyear storage and partly to absorption in talus slides, which, owing to their unstable and porous formation, readily admit the rain water.

The run-off of a mountain watershed is, as a rule, measured at the mouth of canyons and includes both the seepage or normal run-off and the storm run-off. It is the run-off that becomes available for water supply. Measurements of flow on the major streams are made by the United States Geological Survey and the results published in its water-supply papers. The run-off figures of the San Gabriel River used in the preparation of Figures 2 and 4 of Plate 2 were obtained from the water-supply papers of the United States Geological Survey.

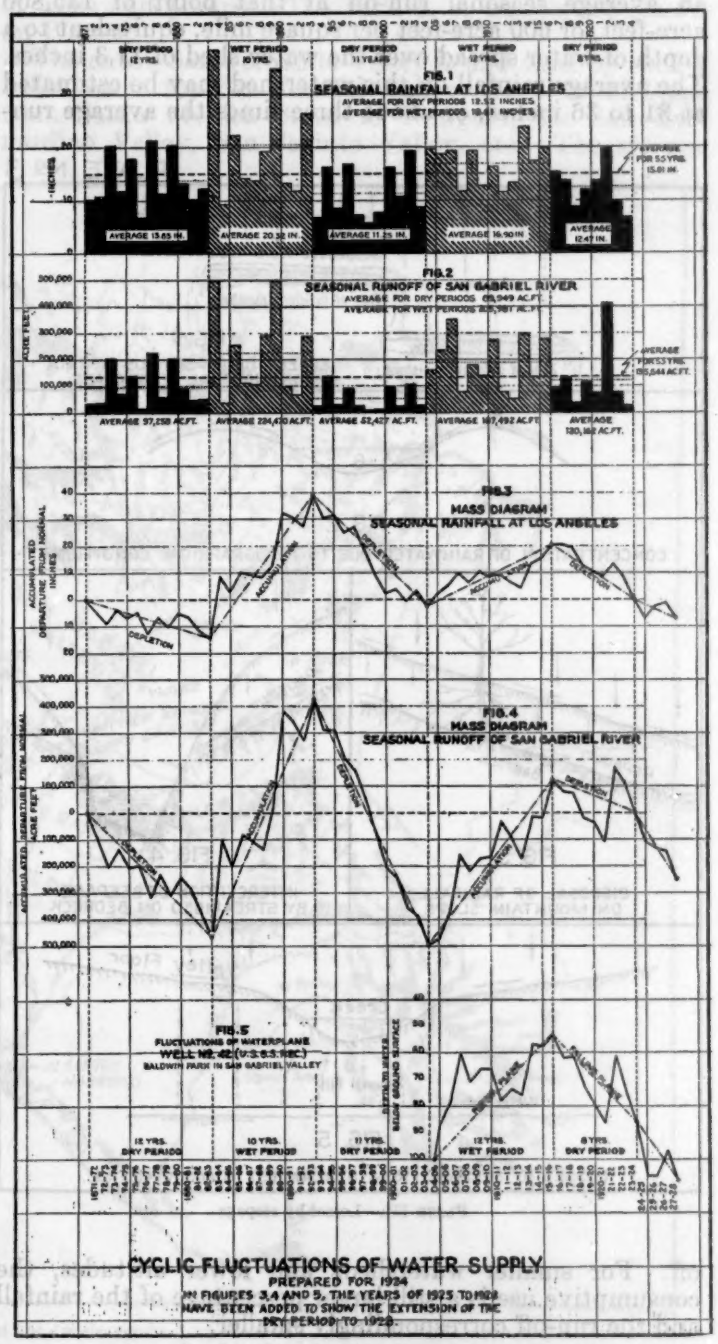

PLATE II.—Seasonal rainfall, Los Angeles, run-off of San Gabriel River, etc., as shown

The consumptive use of a mountain watershed for a 12-month season is obtained from the equation—

Consumptive use = seasonal rainfall minus run-off

A study of the daily discharge of a stream and its hydrograph will readily permit the segregation into seepage and storm run-off, since the latter is characterized by the violent and erratic departures from the more or less uniform normal flow.

For the mountain watersheds it has been found that the consumptive use of the brush or timber cover varies from

20 to 30 inches, and that this is, roughly speaking, two-thirds of the rainfall or total water supply. Of the remaining one-third, by far the larger portion is normal or seepage run-off and only a small part is storm run-off, except in years of heavy floods. The San Gabriel River, with a water shed of 222 square miles above Azusa, has an average seasonal run-off at that point of 135,800 acre-feet, or 600 acre-feet per square mile, equivalent to a depth of water spread over the water shed of 11.3 inches. The average rainfall on this watershed may be estimated at 31 to 36 inches, or about three times the average run-

PLATE Nº 3

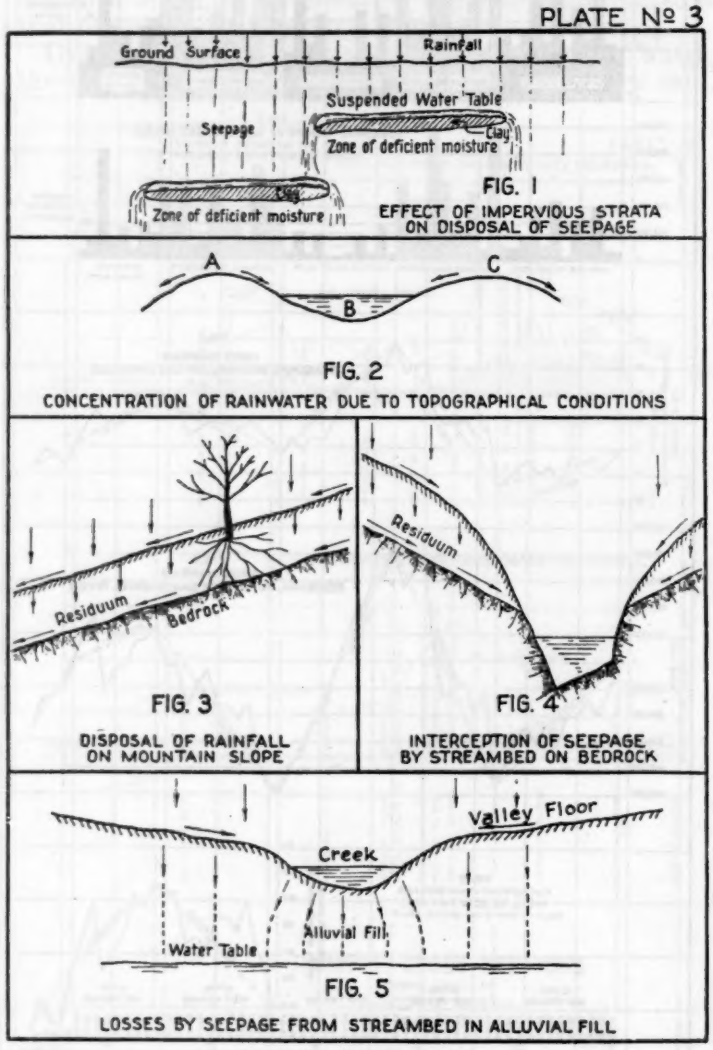

PLATE III.—Losses by seepage

off. For smaller watersheds and lower altitudes, the consumptive use is a still larger percentage of the rainfall and the run-off correspondingly smaller.

The fluctuations of run-off of individual years are even more erratic than the periodical fluctuations. The minimum seasonal run-off of the San Gabriel River occurred in 1898–99 with 9,630 acre-feet, equivalent to a depth of water over the whole watershed of less than 1 inch, and the maximum in the season of 1921–22, with 410,000 acre-feet.

Water supply from rainfall on the valley floor.—Seepage water penetrating intermittently below the limits of evapo-transpiration activity must ultimately cause the wetting to field capacity (or water capacity), either of the entire formation overlying the water table or of well-defined ducts reaching from the surface to the water table. If there is additional seepage from above, there must be a corresponding addition to the water table.

The alluvial deposits of which the fill of our valleys is made up are essentially heterogeneous in formation, consisting of irregular bodies of sand, gravel, and clay, so that the percolating fluid will naturally find lines of least resistance, to the effect that a uniform saturation over large areas and to great depths, is not likely to occur, but rather the formation of more or less defined ducts.

At points where percolating water strikes an impervious stratum, downward movement is interrupted and a suspended water table formed. Gradually lateral percolation is then established and a circuitous route for the percolating fluid is formed until another pervious deposit again permits of more or less vertical movement. Whenever a suspended water table has been formed the drainage from same will cover the edges of the impervious stratum and is likely to collect into trickling streams, as illustrated in Figure 1, Plate 3. These conclusions are supported by the fact that during the process of excavating shafts in alluvial fills it is quite common to strike dry materials alternating with moist materials and occasional streams of water. Inasmuch as alluvial deposits almost invariably show an alternation of pervious and impervious strata, the phenomenon indicated in Figure 1 is probably the one most commonly encountered. Under such conditions only a portion of the alluvial mass between the surface and the ground-water table will be saturated.

The recharge of the ground water may be hastened or delayed by impervious strata. Large clay bodies may not only cause a regulation of an irregular water supply, but they may also provide storage of a magnitude not appreciated because not readily traced.

Absorption is favored by the wedging action of roots, and especially by decayed roots, the latter having a tendency to drain a saturated mass along defined canals.

The intensity and effect of rainstorms is magnified by the irregularities of topography, whether they are the gentle undulations which occur on an apparently true plane, or hog wallows and hummocky undulations as shown in Figure 2, Plate 3. It is apparent that some of the rain falling on points A and C will flow on the surface to the depression B. A 3-inch rain may produce at B a depth of water of as much as 6 inches and a seepage greatly in excess of that at points A and C. This concentration of rain water, therefore, induces a corresponding concentration of seepage and may be responsible, in part, for deep penetration when the seasonal rainfall uniformly absorbed is not sufficient to satisfy the moisture deficiency and evapo-transpiration losses over large areas.

It is therefore concluded that the irregularities of topography, the heterogeneous character of alluvial soils, and the actions of roots all tend to concentrate percolation along lines of least resistance and that a uniform wetting of the soil over large areas, even to the depth of the root zone, is not likely to occur, with the ultimate result that larger portions of the valley rains reach the water table than is commonly assumed.

The quantity of the water supply resulting from rainfall on the valley floor is not readily ascertained and for this reason has in the past often been underestimated. The author has made extensive studies of this phenomenon, and his conclusions have been confirmed by the investigations of the engineers of the United States Department of Agriculture and State department of engineering.

In the San Bernardino Valley, above the lower Santa Anna Canyon, it has been determined that in certain years as much as 40 per cent of the total water-crop

tributary to that valley is from rainfall on the valley floor, and that the contributions from this source exceed 200 acre-feet per square mile.

It goes without further explanation that the gentle rains and light storms of dry years do not produce deep penetration to any extent. It is the rainfall of normal, and particularly of wet years with their heavy storms that causes a substantial recharge of ground-water basins, which can be observed in the response of the water levels in wells. Where clay strata are extensive, this response is lagging, but nevertheless ascertainable. The average proportion of recoverable voids in alluvial streams, these deposits are arranged irregularly, with kidneys of clay interlaced with lenses of gravel or sand. The latter are the waterbearing gravels, which under favorable conditions may carry as much as one-third of voids, or interstices, which are filled with water, this water, in turn, being subject to abstraction by means of wells and pumps. The valleys, or basins, are shown on Plate 4.

The entire San Fernando Valley is underlain by such a basin, as is the San Gabriel Valley, the Coastal Plain from Santa Monica down to Newport, the San Bernardino Valley, San Jacinto Valley, etc. The storage

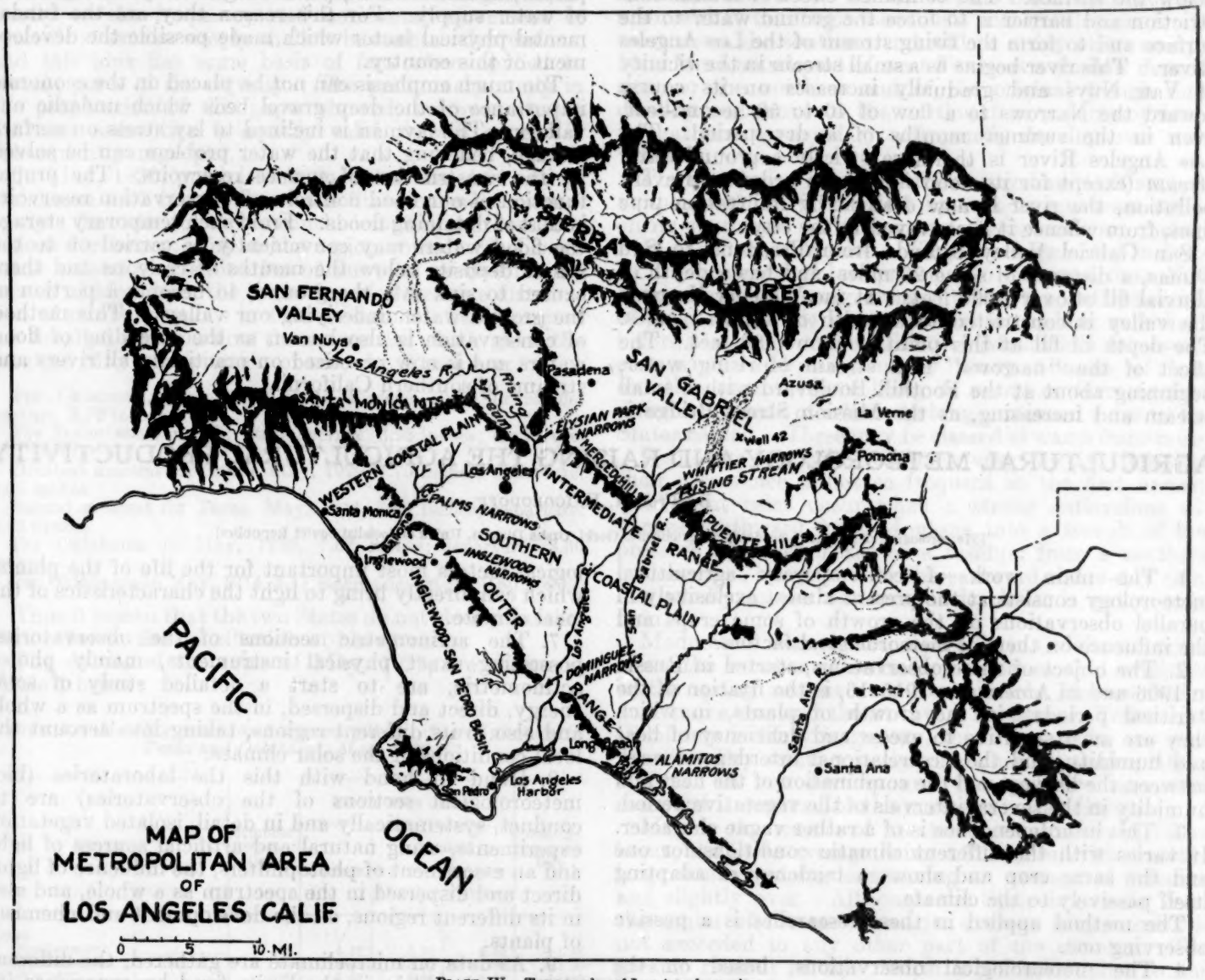

PLATE IV.—Topography of Los Angeles region

materials is about 15 per cent; a rise of the water table by 1 foot over an area of 1 square mile would indicate a recharge of 96 acre-feet, equivalent to a depth of 1.8 surface inches of water.

Ground-water basins.—Even the casual observer will notice that Southern California is dotted with thousands of wells, operated by pumping plants. Probably 75 per cent of the water supply of this country is derived from underground sources. The drilling of great numbers of wells has disclosed that the principal valleys, from the San Luis Rey River northerly to the Sierra Madre Mountains, are underlain by deep basins filled with alluvial materials. Having been laid down by flowing capacity of these basins is so enormous that the capacity of surface reservoirs, even of the size of the San Gabriel Canyon Reservoir, is but a fraction thereof. The recharge of these basins is effected by seepage from streams which cross the valleys and from rain water seeping into the ground of the valley floor and beyond the roots of plant life, ultimately to reach the water table. The ground water, sometimes called the "underflow," percolates as a rule in the general direction of the surface stream. The rate of percolation is generally slow, ranging from 1 to 3 or 4 miles per year. Unless intercepted by barriers, the underflow will in its natural course reach the ocean underground.

A characteristic of most of these basins is the occurrence of underground barriers (dikes) or of lateral constrictions, or both, which interrupt the percolation of the ground-water streams. Taking, for example, the San Fernando Valley, at Van Nuys the valley has a width of 8 miles and a depth to bedrock of 1,000 feet or more. At its outlet the valley is constricted from Burbank to Elysian Park by the approach from either side of the hill formation, narrowing the valley down to a width of three-fourths mile. This is the Elysian Park "narrows." There is, furthermore, an underground sandstone barrier which crosses the narrows at a depth of less than 200 feet below the surface. The combined effect of lateral constriction and barrier is to force the ground water to the surface and to form the rising stream of the Los Angeles River. This river begins as a small stream in the vicinity of Van Nuys and gradually increases on its course toward the Narrows to a flow of 40 to 50 second-feet, even in the summer months of a dry period. The Los Angeles River is therefore strictly a ground-water stream (except for its flood flow). In order to prevent pollution, the river is now drained by infiltration pipe lines, from whence it is conveyed to the city.

San Gabriel Valley extends from Pasadena to San Dimas, a distance of some 20 miles, and has a depth of alluvial fill of over 1,000 feet. At the Whittier Narrows the valley is constricted to a width of about 2 miles. The depth of fill at this point is about 480 feet. The effect of the "narrows" is a stream of rising water, beginning about at the Foothill Boulevard with a small stream and increasing, as the Mission Street Bridge is approached, to a river carrying 60 to 120 second-feet. This supply is diverted in a number of irrigation ditches.

The many narrows constricting our valleys or basins are indicated on Plate 4.

In the ground-water basins water will remain pure and potable for indefinite periods and is available for abstraction over long periods as it percolates from the mountains to the sea.

These ground-water basins present a natural and practical solution for the regulation of the otherwise erratic water supply of southern California, making it possible to store water from a wet period into a dry period; in other words, permitting of a cyclic regulation of water supply. For this reason they are the fundamental physical factor which made possible the development of this country.

Too much emphasis can not be placed on the economic importance of the deep gravel beds which underlie our valleys. The layman is inclined to lay stress on surface storage, believing that the water problem can be solved by the construction of surface reservoirs. The proper function of our flood control and conservation reservoirs is that of detaining floods. From such temporary storage the flood waters may conveniently be carried on to the gravel deposits below the mouths of canyons and there caused to sink into the ground, to become a portion of the ground water underlying our valleys. This method of conservation is also known as the spreading of flood waters and is now practiced on practically all rivers and streams of southern California.

AGRICULTURAL METEOROLOGY AND RAISING THE AGRICULTURAL PRODUCTIVITY

By Prof. A. KAÏGORODOFF

[Meteorological department, academy of agriculture, Gorki, Orsha District, Union of Socialist Soviet Republics]

1. The main work of contemporary agricultural meteorology consists at the present almost exclusively in parallel observations on the growth of some crops and the influence on them of meteorological factors.

2. The object of these observations, started in Russia in 1906 and in America in 1915–16, is the fixation of the "critical periods" in the growth of plants, in which they are most sensitive to excess and deficiency of heat and humidity, and the "correlational interdependence" between the harvest and the combination of the heat and humidity in the several intervals of the vegetative period.

3. This interdependence is of a rather vague character. It varies with the different climatic conditions for one and the same crop and shows a tendency of adapting itself passively to the climate.

The method applied in these researches is a passive observing one.

4. The meteorological observations, based on the contemporary international agreements, have but a limited value in the comparison of climates on broad scales, and their importance for practical agronomy is very small.

5. As a counterpoise to the foregoing and in addition to it, an experimental method is proposed to be applied at special microclimatic stations, observatories, and biometeorological laboratories.

6. The data on microclimate, or rather on bioclimate, are to be gathered by means of observations made with special instruments more exact and more sensitive than the ordinary ones, in the lowest strata of the atmosphere, 0 to 15 meters, having as their object the fixation of the movement and the limits of fluctuations of those meteorological factors most important for the life of the plants, which can directly bring to light the characteristics of the local climate.

7. The actinometric sections of the observatories, possessing exact physical instruments, mainly photoactinometric, are to start a detailed study of solar energy, direct and dispersed, in the spectrum as a whole and also in its different regions, taking into account the local conditions of the solar climate.

8. Hand in hand with this the laboratories (biometeorological sections of the observatories) are to conduct, systematically and in detail, isolated vegetation experiments, using natural and artificial sources of light and an assortment of photophilters, the influence of light, direct and dispersed in the spectrum as a whole, and also in its different regions, on the development and chemism of plants.

9. As data on microclimate are gathered, the different elements should be in the limits fixed by experience for given regions, and introduced into the vegetation experiments as new variables, enabling thereby the calculation of the influence of divers factors of the bioclimate on the growth of different crops.

10. The totality of gathered facts will enable us to fix, with the aid of specialists—chemists, physiologists-botanists, selectioneers, etc.—the climatic "formulary" of the plant, depending on the natural conditions of the region, and thus to tie together the vegetable world with climatic conditions by a causal and uniform nexus.

11. The struggle against the natural forces of a meteorological character is mainly the business of technical and rationalized agriculture; and if it be sufficiently

industrialized, the influence of these forces can be reduced to a minimum. At the same time we can raise the favorable conditions, leaning on a firm scientific basis. The main lines of the struggle are already marked out, and with intense research studies success is assured.

12. If realized, this should give a mighty impulse to the raising to a higher level the quantity of agricultural production, on a basis of broad industrialization and enlarged scale, with reconstruction on a strictly scientific basis.

WEATHER ABNORMALITIES IN UNITED STATES

HEAVY RAINS IN TEXAS AND OKLAHOMA, MAY, 1929

ALFRED J. HENRY

(FIFTH NOTE)

Ordinarily one thinks of the rainfall as being due primarily to the frequency and horizontal movement of cyclonic storms or simply shallow barometric depressions, and this idea has some basis of fact when applied to certain parts of the country. The preliminary study in the preparation of this paper showed, however, that a different conception is equally valid, as will appear in subsequent paragraphs.

In May, 1929, precipitation in Texas was 4.04 and in Oklahoma 3.30 inches above the State normals, respectively. In order to reach a conclusion as to the ideal conditions for heavy rains in the region considered, I have made a detailed examination of the total rainfall for the month of May from the beginning of state-wide distribution of rainfall stations in 1891 to date. I have selected for detailed examination those months which gave the greatest May precipitation of record. These are:

For Oklahoma, May, 1902: State average, 10.13 inches; departure, 5.72 inches.

For Texas, same month: State average, 3.93 inches; departure, 0.27 inches.

Greatest amount for Texas, May, 1929, 7.70 inches; departure, 4.04 inches.

Second greatest for Texas, May, 1914, 7.68 inches; departure, 4.02 inches.

For Oklahoma in May, 1929, 7.67 inches; departure, 3.30 inches.

For Oklahoma in May, 1914, 5.17 inches; departure, 0.80 inches.

Thus it is seen that the two States do not closely parallel each other in the distribution of heavy rains.

The details of the rains of May, 1929, are shown in Table 1 below:

TABLE 1.—*Monthly mean and extreme values of precipitation in Texas and Oklahoma, May, 1929*

Divisions	Number of stations	Precipitation (inches)			Monthly departure
		Average	Greatest		
			Monthly	24 hours	
Texas:					
Northwestern	51	4.37	8.85	6.30	+1.47
Northeastern	26	8.43	15.29	7.00	+3.80
Western	36	3.62	8.86	3.62	+1.13
Central	37	10.88	20.46	7.22	+6.19
Eastern	13	13.48	22.49	11.05	+8.63
Southwestern	47	8.62	17.18	6.16	+5.05
Coast	37	9.42	17.86	7.65	+5.17
Oklahoma:					
Eastern	27	9.15	16.25	4.70	+4.33
Central	26	8.98	12.90	6.50	+3.94
Western	31	5.20	14.78	7.86	+1.96

The detailed examination of the daily weather maps which gave the greatest monthly totals of precipitation for the region under consideration clearly show that the controlling pressure formations are (1) strong anticyclones with central pressure between 30.50 and 30.60 inches overspreading one of the northern tier of States from North Dakota to Michigan; (2) at the same time pressure should be low over the Great Basin, a depression with central pressure of 29.70 to 29.80 inches over Nevada or Utah.

The anticyclone tends to spread fan shaped to the southeast with a slow movement; the Utah depression has a somewhat uncertain movement and development. In most cases the southern end will in a day or so occupy New Mexico and part of west Texas as a shallow depression, or the northern end of the original trough may develop and move to the northeast as a going cyclone; in that case a secondary will usually develop over west Texas.

The circulation proper to the anticyclone as it spreads to the southeast is manifest by east to southeast winds on its southwest periphery, and these winds are mainly from the Gulf of Mexico. They are augmented in force by the presence of low pressure to the west over New Mexico and adjoining areas. When the anticyclone is of great magnitude it may persist for as long as a week before passing over the Atlantic. Meanwhile the southeast winds and rain, locally heavy because of long duration prevail, there being as many as three or four different periods of relatively long-continued rains in the States named. These may be classed as warm front rains.

Rains due to a cold front may vary the situation, but their occurrence is not so frequent as the first named. Cold front rains occur when a strong anticyclone advances southward from Montana into a trough of low pressure left over Texas as a residual from a northern cyclone that has passed to the eastward. A 4-day rain, due wholly to the northern anticyclone, is not uncommon.

Moderately heavy rains, especially in Oklahoma, occur when the number of secondary cyclones that originate in the spring months over the southern Plateau region and move east-northeast over northwest Texas and Oklahoma is fairly large, say, three or four in any one month. Dry weather is the rule when southern plateau cyclones do not develop and the cyclonic movement eastward is confined to the northern border States.

May is the month of greatest precipitation in Oklahoma, the State average being 4.37 inches, with a rather large number of stations having an average of 5 inches and slightly over. Although the State is not far from the center of the continent, its average May rainfall is not exceeded in any other part of the country. The greater rainfall of this month is doubtless due to the large opportunity that is present for vertical convection and also the overrunning and underrunning of air masses of different temperature and moisture content. These conditions are best developed in the months April–June.

The foregoing is, of course, rather broadly generalized; the details of pressure distribution will follow the plan outlined more or less closely, but there will be differences. As an example of the closeness of fit I give the detailed pressure distributions that were responsible for the heavy rains of May, 1929, in Texas and Oklahoma; these were grouped around four separate periods totaling 18 days as given below:

Rains of May 1–4, 1929.—These were cold front rains due to the southeastward advance of an anticyclone

from Wyoming to the Gulf of Mexico in three days in association with low pressure over Texas.

Rains of May 8–9, 1929.—A depression of the barometer moved from the southern plateau on the 7th to Texas on the 8th and dissipated over that State on the 9th, a strong anticyclone in the meantime having advanced from the western Canadian Provinces to the lake region.

Rains of May 16–18, 1929.—As in previous cases, a strong anticyclone and a pronounced fall in temperature was centered on the 15th in Montana, and there was a depression of the barometer over northern New Mexico. This anticyclone moved very rapidly to Iowa by the 16th and to the New Jersey coast in the next 24 hours. Meanwhile Texas and Oklahoma were occupied by a residual low; the winds were southerly and very general rains occurred on the dates named.

Rains of May 26–31, 1929.—The rains of these dates were not quite so general as those already mentioned, but the total for the six days was a very considerable amount at many stations.

On the morning of the 26th a shallow depression of the barometer occupied southeastern Wyoming and an anticyclone of wide extent was centered in the lake region. In the three days immediately following the depression was forced to the south-southeast and gradually dissipated over Texas. Meanwhile the pressure gradient over Texas and Oklahoma was for south to southeast winds, and these are rain winds for the States named.

Finally the dominating weather control being anticyclonic, the temperature will be several degrees below the seasonal average in months of heavy rainfall.

KITE OBSERVATIONS IN MAY, 1929

A brief study of the free-air observations made at the two kite stations of Broken Arrow, Okla., and Groesbeck, Tex., has been made. The geographical coordinates of the stations are as follows:

Broken Arrow, north latitude 36° 02″, west longitude 95° 49″; elevation, 765 feet. Groesbeck, north latitude 31° 30″, west longitude 96° 28″; elevation, 461 feet.

It so happened that barometric formations were favorable for rain in May, 1929, in Texas and Oklahoma on at least 16 different dates; and since the occurrence of precipitation is prejudicial to kite flying, it is not surprising that synchronous flights at both stations were obtained on but seven days and at a single station on four days. The amount of observational material is therefore less than we would wish.

No pretense was made to subject the observations to critical analysis. At most search was made for some obvious relation between the wind direction, the moisture content of the air and its temperature, and the occurrence of rain at the kite stations.

True, the kite observations reveal to a greater or less extent the structure of the immediate section of the atmosphere explored, depending upon the altitude reached. When, however, clouds are present both the temperature and moisture of the air is apt to be in a more or less stratified condition, thus making it difficult to draw inferences of value.

The circulation of the wind in cyclones and anticyclones is already well known so that the added information of the kite flight is of little or no avail.

The significant data afforded by the flights are changes in the decrease of temperature with increase in altitude, changes in the lapse rate, as it is now known, and also changes in the moisture content of air masses that can be identified as coming from higher latitudes (polar air) and from lower latitudes, respectively (equatorial air). Progress is being made toward showing such changes graphically, but the methods thus far in use have not as yet been applied to the kite observations here discussed. I am therefore under the necessity of closing my comment on the kite observations with the statement that they have not thrown additional light upon the physical processes involved in the heavy rains in both Texas and Oklahoma.

THE INFLUENCES THAT BRING ABOUT HEAVY RAINS IN TEXAS AND OKLAHOMA COMPARED

Oklahoma, being farther removed from the source of moisture than Texas, does not respond in the same degree to the influences that produce heavy rains in the last named. The chief cause of heavy rains in Texas and Oklahoma is the combination, low pressure over west Texas, New Mexico, or southeast Colorado, and high pressure to the east-southeast, as in May, 1929, and as may be inferred, the individual months may show slight variations from this general pattern.

It is axiomatic that whenever the progression of a cyclonic system or simply a shallow barometric depression in its northeastward course over the Plains States is blocked by high pressure centered over or to the north of the Great Lakes, especially in the months of May and June, the rains over the States named are heavy and in places of longer duration than usual. Since the movement of the anticyclone from the Great Lakes to the South Atlantic coast may consume three or four days, and since the relative geographic position of the two formations changes but slowly, the long continuance of the rains is thus explained. In further explanation it should be said that the anticyclonic air being relatively and absolutely cooler than the air in the cyclone, a mass movement of the cooler anticyclonic air toward the center of the cyclone or depression must bring about very generous rainfall.

A second cause of general rains in Oklahoma, and in a less degree in Texas, is the origin of secondary cyclones or simply barometric depressions over the southern plateau and their subsequent movement over Oklahoma and western Texas. In some months for reasons that are unknown there is an absence of secondaries in the region named; such disturbances have their origin far to the northward and pass eastward along the Canadian border too far north to give rain in Oklahoma. The problem of predicting the rains of the coming season is therefore an impracticable one at the present time.

The conclusion is reached that heavy rains, particularly in the Plains States, including Texas, are quite as likely to be due to the aberrant movement of cyclones and the resulting development of secondaries as to the frequency of fully organized cyclones that may pass over a given region in the space of a month or more.

It is also apparent that the development of strong anticyclones and their southeastward movement across the United States is an important factor in controlling the rainfall of the Plains States, the lower Missouri and the middle Mississippi Valleys.

Torrential rains in Texas may also be due to the advance inland over that State of a tropical disturbance from the Gulf of Mexico that expends its energy in heavy flood-producing rains.

A MOBILE FIRE WEATHER FORECAST UNIT

By L. G. GRAY

[Weather Bureau Office, San Francisco, Calif.]

Since July, 1926, an intensive fire weather service has been in operation in California. The principal object of this service is an economic one—to aid all fire prevention and suppression agencies in their efforts to reduce losses from forest, grass, grain, and brush fires. That the fire problem in California is economically of great importance is shown by the fact that outdoor fires in 1928 in this State alone caused losses totaling nearly four and one-half million dollars.

The fire weather service of the Weather Bureau was established at the earnest request of fire agencies, which were much impressed with the importance of weather conditions in their effects on fires. The fire weather service works in close cooperation with these agencies, Federal, State, and private.

The term "fire weather" aptly describes those combinations of weather conditions which cause fires or which favor their rapid spread when once started. Lightning, for example, causes from 10 to 45 per cent of all outdoor fires in California, depending on the character of the individual season. Dry and windy weather causes rapid spread and difficult control of fires, however they may have been started.

Severe lightning concentrations in California have caused more than 350 lightning fires on national forests during a single thunderstorm period of two and one-half days. Thunderstorms of the relatively "dry" type thus constitute the fire-causing phase of fire weather.

Hot, dry, windy weather constitutes the fire-spreading phase of fire weather. Atmospheric relative humidity, as it affects the dryness of fuels through its control of the rate of evaporation of fuel moisture into the air, and wind direction and velocity, as the latter influences the evaporation rate, and as both together determine the direction and rate of spread of fires, are generally considered to be approximately of equal importance under California conditions in the production of dangerous fire weather.

Low relative humidity causes drying of forest fuels to a state approaching tinder. Fires once started in such fuel by human carelessness or lightning, spread rapidly when fed with additional oxygen and fanned by the wind. The wind frequently spreads sparks far in advance of the main fire. These sparks cause "spot" fires, which may and often do exceed the parent fire in size and difficulty of control. Rough field determinations have indicated that the rate of spread of fire in grass and low brush varies directly as the square of the wind velocity up to velocities of about 15 miles per hour; at higher velocities the increase in rate of spread is not proportionately so great.

It will be apparent from what has just been said that fire-weather factors are of vital importance in connection with fire prevention and suppression work; that they are practically evident and not mere theoretical abstractions.

The service rendered to fire prevention and suppression agencies by the Weather Bureau is primarily a forecast service. Systematic fire-weather forecasts are issued by the district forecaster of the weather bureau at San Francisco, based on the usual synoptic weather reports and charts, supplemented by daily telegraphic reports from specially established fire-weather observing stations on forest areas.

While the general fire-weather forecasts thus issued are very helpful to fire agencies in planning general fire action the forecasts are not and can not, under the circumstances, be sufficiently specific and adapted to local fire conditions to warrant their use as bases for detailed tactics to be used in suppressing a given fire. The district forecaster has no knowledge of the local topography and cover conditions. Foresters believe that forecasts of the specific type in connection with fire tactics offer the greatest opportunity for economic saving.

In an effort to supply the type of forecasts desired on large going fires, a 26,000-acre fire on the Santa Barbara National Forest was visited during the 1928 fire season and experimental forecasts were issued by a meteorologist on the ground. He was advised daily by wire from San Francisco regarding the general weather situation, and this information was supplemented by detailed observations taken at key points in the vicinity of the fire. This experiment was successful, the forest supervisor commenting that the forecasts furnished were directly helpful in planning the right tactics which led to final control of the fire, and that a considerable saving in suppression costs undoubtedly resulted directly from these forecasts.

Since fires and their complex topographical surroundings can not be taken to the district forecast center for analysis, a mobile weather bureau office has been planned to take equipment and a meteorologist to the fires.

The plan will be put into effect July 1, 1929. A ton-and-a-half truck is being equipped with meteorological instruments for use on the fire area, including anemometers, hydrothermographs, psychrometers, maximum and minimum thermometers, rain gage, and instrument shelters, as well as a barograph and aneroid barometer of smaller size; with radio receivers covering the short wave, long wave, and broadcast bands to copy the twice daily detailed weather broadcasts, including general forecasts, from naval radio station NPG at Mare Island; with charting facilities to prepare synoptic charts similar to those prepared at San Francisco; and with accommodations for the personnel of two men who will operate the unit, a meteorologist in charge, and a combination observer and radio operator.

The unit will travel throughout the entire State during the fire season, being dispatched to going fires by telegraphic orders from a central dispatching agency in the office of the Forest Service at San Francisco. The unit will maintain telegraphic communication with San Francisco and keep the dispatching agency notified of the whereabouts of the unit, actual and prospective. When not engaged on special forecasting work on going fires, the usual fire weather field work, chiefly the establishment of fire weather observing stations on forest areas for survey purposes, will be carried on.

Upon receipt of orders, the unit will proceed immediately to a large going fire, set up radio apparatus, establish temporary check or key weather stations in the fire vicinity, and issue detailed forecasts of weather, wind, temperature, relative humidity, and other factors influencing the choice of fire tactics and the ultimate control of the fire. Forecasts will be of the short period type, issued twice daily, together with such special advices as may be required in connection with backfiring and similar operations.

After the close of the fire season in northern California, it is planned to station the unit at a "fire house"

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or permanent base in southern California to give service on late fall fires common in that part of the State.

The unit will be operated for an experimental period of two fire seasons, the mobile equipment being supplied by the United States Forest Service, the operating expenses being paid by the California State Division of Forestry and the operating personnel and radio and meteorological equipment being supplied by the United States Weather Bureau.

If this novel plan is successful, and no insurmountable obstacles are now apparent, it is probable that three such units will be operated in California, one each in the northern, central, and southern parts of the State. The applicability of this plan to other forested areas in the far West is evident, since the weather data as broadcast from station NPG, on the reception of which the plan depends for success, can be copied almost anywhere west of the Mississippi. The fire agencies of British Columbia are much interested in the working out of this plan, and if successful in this State, consider it desirable to adopt it for their region, equipping launches instead of automobile trucks.

This plan will be on trial during the next two fire seasons in California. Past experience with this system on large going fires shows the plan to have much promise. We have reason to believe that successful operation of the system will be of far-reaching importance and application to organized fire protection work.

THE RECORD OF EVAPORATION STATIONS IN CALIFORNIA

By ERNEST E. EKLUND

[Weather Bureau Office, San Francisco, Calif., June 21, 1929]

Of the various climatic factors that have always an important, and sometimes predominant, influence on the economic development of a nation, state, county, or city, evaporation is one of more than academic interest throughout the semiarid Southwest, and particularly in California. Here the development of intensive farming and of hydroelectric power is dependent upon an average seasonal precipitation of approximately 25 inches, occurring during a few winter months. The snow pack that accumulates in the higher mountains during the winter is equivalent to an immense reservoir that keeps many streams flowing through all or part of the practically rainless summer, and in addition many huge reservoirs have been constructed to supply water for civic uses, for operating hydroelectric power plants and for irrigating many thousands of acres of farming land. A large portion of the water impounded, and of that distributed over the land in irrigation, is lost by evaporation. For this reason the question of evaporation becomes of considerable importance in the economic development of California.

The first evaporation measurements made in California, of which we have a record, were begun in 1881 at Kingsburg by the State department of engineering, but the first measurements of evaporation undertaken by the Weather Bureau were those made 20 years ago at Salton Sea and at auxiliary stations. It was not until 1918 that stations were established on a permanent basis with the standard class A equipment, now in use. At that time, records were being made at Lake Tahoe, using a floating pan, but in 1918 three stations were established, using land pans according to the present Weather Bureau standard. Two of these stations have been in operation ever since; one was closed of necessity in 1923. In 1924 and in 1925, two additional stations were established, making five stations cooperating with the Weather Bureau at the present time.

More than the usual number of requests for evaporation data were recently received at the San Francisco Weather Bureau Office and, as it was known that some evaporation records had been made or were being made in California without the cooperation of the Weather Bureau, efforts were made to learn what additional records might be available. A card was mailed to all California addresses that received Climatological Data—California Section. The card read: "The Weather Bureau is desirous of obtaining information relative to evaporation measurements in California that have been made, or are now being made, without the cooperation of the Weather Bureau. If you know of any such evaporation records, kindly give the information requested in the blank spaces below, and mail this card which requires no postage." The blank spaces were for the names and addresses of the persons making and reporting the observations. The response was immediate and gratifying. Many of the returned cards related to evaporation records, but the majority offered the use of other kinds of records or reported "no records known." The cards were followed up by circular letters and questionnaires addressed to the persons who were reported as having made evaporation measurements.

From the information thus obtained, a table has been compiled, the stations being arranged approximately in geographical order from north to south. In the table are included a few stations that are beyond the borders of the State but which may be considered as having the same climatic characteristics as the adjacent portions of California. The table is known to be incomplete but contains some information about most of the evaporation records that have been made in California. Unless otherwise stated, the evaporation was measured from fresh water. No attempt has been made to collect the actual records, for to assemble them in a manner that would render them useful would be practically impossible. Any attempt to correlate all of them would be hopeless, due to the great dissimilarity of equipment and methods and, in some cases, to the lack of specific information as to the conditions under which the measurements were made. A map is also presented (not reproduced), on which the stations are numbered as in the table, but all records made in any given locality are listed under one number. It is interesting to note on the map that the stations are most numerous in those sections of California where irrigation and power projects have reached their highest development; also that they are numerous in the extreme southern portion where precipitation is comparatively light, and totally lacking in northwestern California where precipitation is heaviest.

Why have so many evaporation measurements been made in California? The factors determining evaporation from free water surfaces are generally agreed upon by physicists, meteorologists, and engineers but, despite the fact that the laws of evaporation have been investigated for centuries, a satisfactory method for computing the evaporation from a water surface already existing, or from such a surface to be created by constructing a reservoir, has been hard to find, and opinions still differ as to the proper method of measuring evaporation from a free water surface. Great variations in temperature, relative

humidity, wind movement, elevation, and other climatic influences are to be found in California, and many of the evaporation measurements in California have been made by hydraulic engineers in an effort to make proper allowance for evaporation losses from a reservoir to be constructed. In some cases the measurements have been made to determine whether the losses in a water system were due to evaporation from the reservoir or to other causes, such as seepage or pipe-line leaks. Also confronting the hydrologist are other problems wherein he must consider evaporation, whether it be from snow, fresh water, brine, moist soil, or vegetation. In the commercial production of certain chemicals from mineralized deposits or waters, evaporation is highly important, and some of the evaporation records in California have therefore been made by chemical engineers.

Another group of observations has been fostered by agricultural interests, for use in various problems relating to irrigation practice, the water requirements of crops and to plant pathology. A few experiments have been made by physicists searching for more knowledge of the laws of evaporation or attempting to correlate records obtained from dissimilar types of equipment. A notable example of work of this kind is to be found in the experiments conducted at the California Institute of Technology at Pasadena by Prof. N. W. Cummings and others. It is claimed that a method for computing evaporation from a large water surface was developed as a result of these experiments.

Thus far there has been little cooperation among the several interests concerned in the making of evaporation records. In general, where sufficient time could be allowed, each person requiring evaporation data has set out to obtain them by actual measurement. No doubt helpful data could have been found had one known where to look, but until now no attempt has been made even to list the records that have already been secured. In this way, it is believed the table and map that have been prepared will be found of value for reference purposes.

	Station	Records made by—	Duration		Equipment	Remarks
			From—	To—		
1	Klamath Falls, Oreg	Calif.-Oregon Power Co	August, 1921	Present	Floating pan, 22 by 42 inches, circular, submerged 13 inches.	Records at Office of U. S. Geological Survey, Medford, Oreg.
2	A. Canal, Klamath Falls, Oreg.	Reclamation Service	July, 1917	June, 1918	Floating pan, 10 inches by 4 feet, circular.	Original records at Office of Bureau Reclamation, Klamath Falls, of Oreg.
3	Adams Boat Landing, Oreg.	do	May, 1913	September, 1918.	do	Do.
4	Lower Lost River Diversion Dam, Oreg.	do	February, 1924	November, 1925.	Floating pan, 10 inches by 3 feet, circular, submerged 4 inches.	Do.
5	Clear Lake (Modoc County), Calif.	do	April, 1911	November, 1913.	Floating pan	Do.
6	Coppocks	do	May, 1916	August, 1923	Floating pan, 10 inches by 4 feet, circular.	Do.
7	Yreka[1]	Forest Service	July 4, 1925	Oct. 10, 1925	Porous cup atmometer (distilled water).	Original records at office of Forest Service, Yreka, Calif.
8	Fall River Mills (near)	Pacific Gas & Electric Co. and Weather Bureau.	do	Present	Class A, Weather Bureau standard.	Published in Climatological Data—California section.
	do	do	do	do	Floating pan, 10 inches by 4 feet, circular.	Records at Weather Bureau Office, San Francisco, Calif.
9	Prattville	Great Western Power Co	Aug. 1, 1924	do	Floating pan, 18 inches by 3 feet square, painted white.	Records private property.
	do	do	Aug. 6, 1924	do	Pan, 3 by 3 feet, circular, embedded in ground.	Do.
10	Big Meadows Dam	do	Aug. 13, 1924	do	Floating pan, 18 inches by 3 feet, square, painted white.	Do.
	do	do	Mar. 27, 1925	do	Pan 3 by 3 feet, circular, embedded in ground.	Do.
11	Butte Valley Dam	do	Aug. 1, 1924	do	Floating pan, 18 inches by 3 feet, square, painted white.	Do.
12	Chico	U. S. Department of Agriculture and University of California.	1904	1905	Tanks set in ground (moist soil)	Records summarized in Experiment Stations Bulletin No. 177.
13	Dodgeland	Dodge Land Co. and Weather Bureau.	Sept. 21, 1918	December, 1922	Class A, Weather Bureau standard.	Published in Climatological Data—California section.
14	Biggs	United States rice field station	1913 (April to October).	1925 (April to October).	Tank set in ground	Original records at United States rice field station, Biggs, Calif.
15	Norman (near)	University of California	1918	1919	Pan, 18 by 20 inches, circular	Records at division of irrigation, college of agriculture, Davis, Calif.
16	East Park Reservoir	Bureau of Reclamation	1911	1923	Floating pan, 10 inches by 4 feet, circular.	Records on file with Bureau of Reclamation.
17	Tahoe	Geological Survey and Reclamation Service.	1900	1906	Floating pan, 2 inches by 8 feet square.	Records summarized in Engineering News, Feb. 29, 1912.
	do	Weather Bureau	July, 1916	Present	Floating pan, 10 inches by 4 feet, circular.	Published in Climatological Data—California Section; also Nevada Section.
18	Cortena rice field	University of California	1922	do	Pan	Records at division of irrigation, college of agriculture, Davis, Calif.
19	Davis	do	1911 (summer only).	1918 (summer only).	Specially designed tank, embedded in ground.	Do.
	do	do	Aug. 2, 1924	Oct. 3, 1924	Specially designed tank (moist soil).	Original records at engineering office, Bureau of Public Roads, Federal Building, Berkeley, Calif.
20	Point Reyes	Weather Bureau	July 21, 1910	Nov. 4, 1910	Evaporometer; 2 pans	Record unsatisfactory due to high winds.
21	Berkeley	University of California and U. S. Department of Agriculture.	1904	1905	Tanks set in ground	Results summarized in Experiment Stations Bulletin No. 177.
22	Oakdale (near)	South San Joaquin irrigation district and Weather Bureau.	Mar. 1, 1918	Present	Class A, Weather Bureau standard.	Published in Climatological Data—California Section.
	do	do	June 11, 1921	Sept. 25, 1921	Floating pan, 10 inches by 4 feet, circular.	Records at Weather Bureau Office, San Francisco, Calif. (not published).
23	Lake Eleanor	City and county of San Francisco	July, 1910	September, 1918.	do	Records at office of water resources branch, U. S. Geological Survey, customhouse, San Francisco, Calif.
24	Dallas (and Warner) Reservoir.	Modesto irrigation district	1914	1914	Floating pan, 18 inches by 3 feet, square.	See Engineering News, Aug. 12, 1915.
25	Don Pedro Reservoir	Turlock and Modesto irrigation district.	Apr. 13, 1924	Present	Floating pan, 15 inches by 3 feet by 4 feet.	Records at office of Turlock irrigation district, Turlock, Calif.

[1] Atmometers are in use at a number of Forest Service stations but only 2 representative stations are listed.

	Station	Records made by—	Duration		Equipment	Remarks
			From—	To—		
26	Alvarado (near)	Leslie-California Salt Co. and Weather Bureau.	Aug. 1, 1924	Present	Class A, Weather Bureau standard.	Published in Climatological Data—California Section.
72	Calaveras Reservoir	Spring Valley Water Co	March, 1915	June, 1918	2 floating pans, 18 by 47 inches, circular, painted black.	Records in engineering department, Spring Valley Water Co., San Francisco, Calif.
28	Mountain View (near)	University of California	Sept. 1, 1921	Jan. 1, 1923	Tank, 3 by 3 feet, circular, embedded in ground.	Records at division of irrigation, college of Agriculture, Davis, Calif.
29	Delhi	do	Dec. 15, 1921	Oct. 15, 1928	do	Do.
30	Coyote (near)	Edwin Duryea, jr.	1904	1905	11 pans, 12 inches by 3 feet square.	Summarized in Engineering News, Feb. 29, 1912.
					No. 1, Weber Dam site (land)	
					No. 2, Lower Gorge (land)	
					No. 3, Bailey Avenue (land)	
					No. 4, Laguna Seca, north (land)	
					No. 5, Laguna Seca, west (land)	
					No. 6, Laguna Seca, west (floating).	
					No. 7, Laguna Seca, east (floating)	
					No. 8, San Felipe Dam (land)	
					No. 9, San Felipe Reservoir (land)	
					No. 10, Upper Gorge (land)	
					No. 11, Upper Gorge (floating)	
31	Bass Lake	San Joaquin Light & Power Corporation.	1912	Present	Floating pan, 18 inches by 3 feet, square.	Records at office of San Joaquin Light & Power Corporation, Fresno, Calif.
32	Huntington Lake	Southern California Edison Co	1917	1921	Floating pan	Engineering department, Southern California Edison Co. considers record unreliable.
33	Spreckels	Spreckels Sugar Co	1917	1918	Circular pan, 6 feet in diameter, on surface of ground.	Records private property.
34	Independence (near)	Charles H. Lee for city of Los Angeles.	August, 1908	May, 1911	Pan, 10 inches by 3 feet, square, on ground.	See Transactions American Society of Civil Engineers, Vol. LXXVIII (1915).
					Pan, 10 inches by 3 feet, square, floating.	
					Tank, 4 feet by 3 feet 6 inches, circular, embedded in ground.	
	Independence (near)	Do	June, 1910	May, 1911	Tanks, 6 feet 6 inches by 7 feet 5 inches, circular, embedded in ground (moist soil).	Do.
35	Soldier's Camp (near Lone Pine).	University of California and U. S. Department of Agriculture.	1905	1905	Tanks set in ground	See Office of Experiment Stations, Bulletin No. 177.
36	Owens Lake	Charles H. Lee for city of Los Angeles.	1905	1915	Owens Lake basin considered as an evaporation pan; results checked by evaporating Owens Lake brine in laboratory.	Summarized in Monthly Weather Review, February, 1924.
37	Kingsburg (near)	California State Engineering Department.	November, 1881	Octtober, 1885	Floating pan, 15 inches by 3 feet, square.	See Physical Data and Statistics, 1886, published by State of California.
					Pan, 15 inches by 3 feet, square, set 10 inches into ground.	
38	Tulare	University of California and U. S. Department of Agriculture.	1903	1905	Tanks set in ground (also moist soil).	Summarized in Office of Experiment Stations, Bulletin No. 177.
39	Trona	American Trona Corporation	Mar. 24, 1920	Oct. 1, 1920	Pan, 10 inches by 4 feet, circular, on surface of ground (also brine).	Records private property.
40	Little Bear Valley	Arrowhead Reservoir Co	March, 1895	May, 1897	3-foot pan floating in concrete basin, surrounded by 1 foot of water (also snow).	See Journal of Electricity and Western Industry, May 15, 1921.
41	Mount Wilson[1]	Forest Service	Indefinite period, summer only.	Indefinite period, summer only.	Porous cup atmometer (distilled water).	Records at office of U. S. Forest Service, Los Angeles, Calif.
42	Pasadena	California Institute of Technology	June 23, 1926	July 3, 1926	Tank, 5-foot, cubical; pan, 18 inches by 2 feet, square (both insulated).	See Physical Review October 1927, vol. 30, p. 527, and Bulletin No. 68, National Research Council.
43	Pomona (near)	University of California and U. S. Department of Agriculture.	1903	1905	Tanks set in ground	See Office of Experiment Stations Bulletin No. 177.
44	Riverside (Arlington Heights).	do	June 24, 1905	Sept. 29, 1905	do	Do.
	Riverside	Bureau of Plant Industry	Mar. 16, 1923	Present	Porous cup atmometer, (distilled water).	See (1) Ecology, Vol. VI, No. 3, July, 1925, (2) Phytopathology Vol. XV, No. 8, August, 1925. Records made on similar plan at Shafter, Watsonville (1925 only) and near Torrance, Calif. Unpublished records at office of cotton, truck, and forage crop disease investigations, Bureau of Plant Industry, Washington, D. C.
	do	Citrus Experiment Station	October, 1924	do	Similar to class A Weather Bureau standard except pan is 2 feet above ground.	Records at Citrus Experiment Station, Riverside, Calif.
45	Whitewater Ranch	Coachella Valley County water district.	January, 1920	January, 1921	Pan, 18 inches by 3 feet, circular, set 16 inches into ground.	Records private property.
46	Indio	Weather Bureau (auxiliary to Salton Sea experiments).	October, 1907	November, 1907	Pan, 6-foot, circular, on ground	See monthly Weather Review, February, 1910.
			July, 1908	November, 1908	Pan, 2-foot, circular, on 10-foot tower.	Do.
	do	United States date garden	Jan. 1, 1923	Present	Pan, 15 inches by 3 feet by 8 feet, on ground.	Records at United States date garden, Indio, Calif.
47	Mecca	Weather Bureau (auxiliary to to Salton Sea experiments).	July, 1908	November, 1908	Pan, 6-foot, circular, on ground	See monthly Weather Review, February, 1910.
					Pan, 2-foot, circular, on 10-foot tower.	
48	Salton Sea	Weather Bureau	June 14, 1909	Nov. 1, 1909	4 towers, with pans, 2, 4, and 6-foot, circular, at various heights above land and water.	Do.
49	Mammoth	Weather Bureau (auxiliary to Salton Sea experiments).	1907	1908	Pan, 6-foot, circular, on ground	Do.
					Pan, 2-foot, circular, on 10-foot tower.	Do.
50	Brawley	do	1907	1908	do	Do.
51	Calexico	University of California and U. S. Department of Agriculture.	1903	1905	Tanks set in ground	See Office of Experiment Stations Bulletin No. 177.

[1] Atmometers are in use at a number of Forest Service stations but only 2 representative stations are listed.

	Station	Records made by—	Duration		Equipment	Remarks
			From—	To—		
52	Mexicali, Mexico	Primera Zona de Irrigacion	July 13, 1923	Present	Zinc pan, 1.22 meters, circular, above ground.	Records available at office of Primera Zona de Irrigacion, Mexicali, Mexico.
53	Bard	Bureau of Plant Industry	1910	do	Tank, 30 inches by 6 feet, circular, embedded in ground.	See published reports of the work of the Yuma experiment farm.
54	Yuma, Ariz.	University of Arizona and Weather Bureau.	July 1, 1917	do	Class A, Weather Bureau standard	Published in Climatological Data—Arizona Section.
55	Yuma, Ariz. (near)	do	September, 1920	do	do	Do.
56	San Luis Rey Valley	Geological Survey	1914	1915	Entire valley considered as an evaporation pan.	See Water Supply Paper No. 446, United States Geological Survey (1919).
57	Lake Hodges Dam	San Dieguito Mutual Water Co.	1914	Present	Pan, 18 inches by 3 feet, square, set 12 inches into ground.	Now under control of City of San Diego, Calif.
58	Cuyamaca Reservoir	Cuyamaca Water Co	1913	do	Pan, 18 inches by 3 feet, square, set 16 inches into ground.	Records available at office of La Mesa, Lemon Grove and Spring Valley irrigation district, La Mesa, Calif.
59	Murray Reservoir	do	1912	January, 1928	Floating pan, 18 inches by 3 feet, square, submerged 12 inches.	Do.
60	Sweetwater Dam	Sweetwater Water Corporation	1889	1919	Floating pan, 18 inches by 3 feet, square.	Summary available at company office, National City, Calif.
61	Chula Vista	Western Salt Works and Weather Bureau.	Sept. 1, 1918	Present	Class A, Weather Bureau standard.	Published in Climatological Data—California Section.
62	Morena Dam	City of San Diego	November, 1915	do	Floating pan, 18 inches by 3 feet, square, submerged 16 inches.	Records in operating department, city hall, San Diego, Calif.
	do	do	August, 1925	do	Pan, 18 inches by 3 feet, square, embedded in ground.	Do.
63	Barrett Dam	do	August, 1923	do	Floating pan, 18 inches by 3 feet, square, submerged 16 inches.	Do.
	do	do	August, 1925	do	Pan, 18 inches by 3 feet, square, embedded in ground.	Do.
64	Upper Otay Dam	do	April, 1916	July, 1921	Floating pan, 18 inches by 3 feet, square, submerged 16 inches.	Do.
	do	do	August, 1925	Present	Pan, 18 inches by 3 feet, square, embedded in ground.	Do.
65	Lower Otay Dam	do	November, 1915	December, 1915.	Floating pan, 18 inches by 3 feet, square, submerged 16 inches.	Do.
			August, 1920	Present		
	do	do	August, 1925	do	Pan, 18 inches by 3 feet, square, embedded in ground.	Do.

NOTES, ABSTRACTS, AND REVIEWS

Anders Ångström on the atmospheric transmission of sun radiation and on dust in the air,[1] *by H. H. Kimball.*—The author remarks that the overwhelming interest of Smithsonian Institution investigators in variations in the solar output of radiant energy is perhaps responsible for the comparatively slight use that has been made of their valuable data on atmospheric transmission in detailed studies of the way in which the atmosphere acts on the radiation that penetrates it. For example, during the years 1923–1928, while the range from minimum to maximum in the annual mean values of the solar constant has been only about 0.5 per cent, the range in corresponding annual amounts of solar radiation reaching the surface of the earth at Stockholm has been 25 per cent.

Three general ways in which the atmosphere depletes radiant energy passing through it are given as follows:

(1) Selective absorption by the gases of the atmosphere.
(2) The scattering or diffusing effect of the atmosphere.
(3) The scattering by atmospheric dust.

The loss by reflection from cloud surfaces is not here considered.

The major part of the loss by selective absorption is due to the absorption in the infra-red part of the spectrum by water vapor, the relation of which to surface water-vapor pressure has been determined by Fowle. Likewise, the scattering by gas molecules may be computed by means of Rayleigh's equations as modified by King.

The law of the scattering of radiant energy by atmospheric dust is not so well known. The expression for scattering by gas molecules contains the expression $\frac{1}{\lambda^4}$, where λ is the wave length of the radiant energy. It has generally been assumed that scattering by dust is independent of the wave length, but since dust particles vary greatly in size, Ångström concludes that in the expression for scattering by dust the exponent of λ must be greater than 0 and less than 4, and that the scattering may be expressed by $\gamma=\frac{\beta}{\lambda^\alpha}$.

From computed values of the transmission for dust-free air for wave lengths free from selective absorption, and observed values of the transmission at different places for the same wave lengths, Ångström computed the values of α and β given in Table 1.

TABLE 1.—*Data on scattering of solar radiation by dust*

Stations	Altitude above sea-level	Average conditions		Haziest days for August, 1921		Authority
		β	α	β	α	
	Meters					
Washington	35	0.098	1.24			Smithsonian Institution.
Upsala	35	(.090)	(.70)	0.362	0.515	Lindholm, 1912.
Bassour	1,160	.031	1.22	.255	.53	Smithsonian Institution.
Hump Mountain	1,500	.031	1.33			Do.
Mount Wilson	1,780	.018	1.26	.205	.70	Do.
Calama	2,250	.023	1.33			Do.

The author points out that β is the scattering by dust for radiation at $\lambda=1$ micron without regard to the value of α. Also, if the depletion due to scattering by dust were independent of λ, α should equal zero. Actually, however, Table 1 shows that under average conditions α varies but little from 1.28 over a wide geographical range, and at widely different altitudes, and that the haze caused by the eruption of Katmai Volcano in June, 1912, increased the value of β about tenfold, and greatly reduced the value of α.

From the values of α in Table 1 it appears that the size of the dust particles is independent of height above

[1] Geografiska Annaler 1929, H. 2.

sea level. This is contrary to measurements of the diameters of dust particles collected by means of an Owens dust counter by Mr. Hand during airplane flights up to 10,000 feet. It must be remembered, however, that in general such dust as is present in the atmosphere at a place like Calama, Chile, for example, is principally of local surface origin, and should not differ in size from surface dust at sea level.

Ångström's determinations fix the average diameter of atmospheric dust particles under normal conditions at about 1 micron, and indicate a considerable increase in diameter in August, 1912, when the source of the dust was principally the explosive eruption of Katmai Volcano in Alaska. From the width and angular dimensions of Bishop's ring, which has been shown to result from the diffraction of light by volcanic dust, the diameter of these dust particles has been computed to be 1.85 microns.

Ångström also finds that the variation in the value of β with height may be expressed by the equation $\beta_h = \beta_o e^{-\delta \times h}$ where $\delta = 0.69 \times 10^{-5}$; and, similarly, that the vertical variation in the number of atmospheric dust particles, as determined by Hand's measurements, may be expressed by the equation $N_h = N_o e^{-\phi \times h}$, where $\phi = 0.7 \times 10^{-5}$. It will be noted that the exponent of e in the two equations is practically the same.

Adopting for β_o and N_o the values 0.094 and 400, respectively, or approximately the mean of their respective values for Washington and Upsala, Ångström derives for Σ N, the number of particles in a vertical column 1 square centimeter in cross section, the value 5.6×10^7 He also derives the general expression $\beta = 1.79 \times 10^{-9} \Sigma$ N. From this latter the monthly mean values of β have been computed for Washington. They show a marked annual variation, with a maximum of 0.157 in May and a minimum value of 0.051 in November and December. As the author states, this does not agree with the annual variation in the number of dust particles found at the surface; but when we consider the probable value of the monthly means of Σ N we must take into account the difference in vertical distribution found by airplane measurements in August and November. Therefore, since convection is most active in late spring and early summer, and least active in late fall and early winter, there is nothing incongruous in the annual variation of β.

Summarizing, a more accurate way seems to have been found for computing the solar-spectrum energy distribution at the bottom of the atmosphere, except in the ultra-violet, where actual measurements are required. Also, the size of the dust particles as indicated by the value of α should be a clue to their source. For example, dust particles of volcanic origin appear to be larger than dust particles from the surface of the ground, while cosmical dust particles, which are thought to have been observed at times of sunspot maxima, probably are smaller.

Temperature distribution up to 25 kilometers over the Northern Hemisphere.—K. R. Ramanathan, meteorological department, Poona, India, has published in Nature (London), June 1, 1929, a very interesting chart showing the distribution of temperature up to 25 kilometers over the Northern Hemisphere for summer and winter. (Fig. 1.) The broken lines (except that for 0° C.), the author states:

> Are based on very few observations, and are therefore mainly conjectural. The principal features of the diagram may be briefly summarized.
>
> (1) The stratosphere is not isothermal over any particular place, but above a certain level there is a tendency for the temperature to increase with height.
>
> (2) The coldest air over the earth, of temperature about 185° A., lies at a height of some 17 geodynamic kilometers[1] over the Equator in the form of a flat ring surrounded by rings of warmer air.
>
> (3) The surface of the tropopause has a relatively steep slope toward the pole between latitudes 30° and 50° in summer and between 25° and 45° in winter
>
> (4) The ring of lowest temperature at the tropopause is displaced toward the summer hemisphere.
>
> (5) There is a ridge of high temperature in the tropopause between latitudes 20° and 40° north in summer corresponding to the ridge of high pressure at 8 kilometers over those latitudes. (See Sir Napier Shaw's chart of 8 kilometers isobars in July, Manual of Meteorology, vol. 2, p. 262.)

A comparison of this chart has been made (by the reviewer) with the results of some recent aerological observations made in this country which were not included in the data comprising the chart. The average height and temperature of the tropopause as determined from a sounding balloon series made at Royal Center, Ind., in May, 1926, and at Groesbeck, Tex., in October, 1927, are

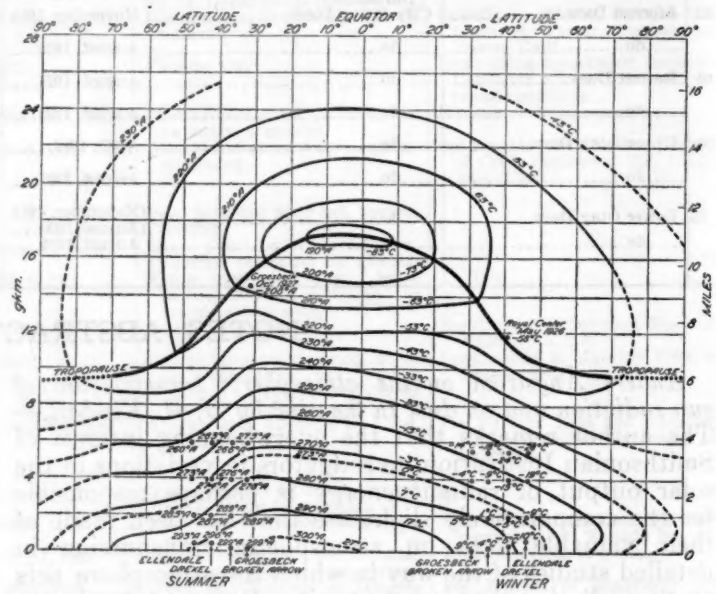

FIGURE 1.—Distribution of temperature up to 25 kilometers over the Northern Hemisphere

found to be in close agreement with the data depicted. These values are indicated at the corresponding points on the chart.

There are also indicated for comparison purposes the average temperatures at various heights as determined for summer and winter from kite observations made at four aerological stations in the United States, viz., Ellendale, N. Dak., latitude 45° 59′; Drexel, Nebr., latitude 41° 20′; Broken Arrow, Okla., latitude 36° 02′, and Groesbeck, Tex., latitude 31° 30′. While all of the latter do not coincide with the smoothed isotherms of the diagram, the general agreement is good, and the differences found are undoubtedly real and due to the greater extremes in temperature found in continental United States as compared to Europe.—*L. T. Samuels*

How high is the ozone layer?—By Charles Fitzhugh Talman.—For many years it has been known that a relatively large amount of ozone is present at high levels

[1] The following quotation from Manual of Meteorology, Volume 2, p. xx, by Sir Napier Shaw, will explain what is meant by geodynamic kilometers: "There is a good deal of laxity about the use of the word height, of the same kind as that of the aeronauts who graduate a pressure instrument to read what they call height. For example, V. Bjerknes and others would express the height of a point in the atmosphere by the geopotential at the point, calling the quantity expressed the dynamic height. We reproduce from the *Avant Propos* of the *Comptes rendus des jours internationaux*, 1923: 'The relation of the geopotential at any position to the geometric height of that position h and the gravitational acceleration g is $\Gamma = \int g dh$. The value is governed accordingly by the local value of gravity depending on the attraction of gravitation and the rotation of the earth, but not to any appreciable extent upon the condition of the atmosphere at the time of observation.'"

in the atmosphere, while only insignificant amounts are ever found, under natural conditions, near the earth's surface. The total amount present over any region can be measured, since the ozone absorbs sunlight of certain wave lengths and the amount of absorption can be determined with the spectroscope. On an average, it is found that the amount of this gas is such that, if it were under a pressure of one atmosphere and at a temperature of 32° Fahrenheit, it would make a layer about 0.12 inch thick. The actual amount is, in general, much greater in high latitudes than in low latitudes, and outside of the Tropics it is subject to rather wide variations, some of which appear to be connected with weather changes and have been the subject of much discussion.

A number of recent measurements have been made of the height of the "ozone layer" in the atmosphere. The method consists of measuring the absorption of sunlight due to ozone both when the sun is high and when it is low. The amount of absorption will vary with the length of the sunlight's path through the absorbing layer. When the sun is high the length of path through the layer will be the same whether the layer is high or low. When the sun is low (i. e., near sunrise or sunset), the path through the ozone layer will, on account of the curvature of this layer conforming to that of the earth, be longer if the layer is low than if it is high.

These measurements indicate that the average height of the ozone layer is between 25 and 30 miles. There is some evidence that its height varies, to a certain extent, with seasons and otherwise.

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Is the semidiurnal barometric variation an electric phenomenon?—Prof. Fernando Sanford, in an article with the above title in Science, April 19, 1929, suggests that there is a very important relationship between the semidiurnal barometric variation and the semidiurnal electrometer variation. The method of presentation is graphic, and as the graphs can not be reproduced here, only a brief summary of the conclusions can be given.

Meteorologists have long felt that the 12-hour pressure variation, because it follows true local time, must be caused by some agency that does not affect the other meteorological elements, but hitherto no such agency has been discovered. Experiments with especially insulated electrometers have shown that "any insulated, unelectrified body near the surface of the earth, even if inside a closed hollow conductor, will be attracted twice daily by the electric charge of the earth, and it has seemed possible that the semidiurnal variation in barometric pressure may be due in some manner to this attraction. To test this surmise the diurnal variation in pressure as shown by the microbarograph was measured and recorded for the same 20 days for which the electrometer deflections were recorded." A graph of the two curves shows a considerable similarity between them.

"One thing that seems certain," says Professor Sanford, "is that the semidiurnal barometric variation is caused in some manner by solar influence. This is shown by both its daily and seasonal variations. Also the semidiurnal electrometer deflection must be due to the sun, as it has both a daily and a seasonal variation, being of greatest amplitude at the equinoxes and least at the solstices. In this respect it agrees closely with the semidiurnal curve. * * *

"There seems to be no reasonable doubt that the cause of the electropositive condition of the earth and the electronegative condition on the night side are due to the electrostatic induction of the sun's negative charge."—*N. H. B.*

Investigation of the oscillations of the general circulation (conclusion)[1]*—By A. Wagner, Innsbruck, Austria.*—The decades 1886–1895 and 1911–1920 were investigated with relation to change in the distribution of the different meteorological elements over the whole earth. These changes, represented in five charts, show the following:

1. The contrasts in air pressure, as they appear from the distribution of mean values over the earth's surface, are heightened in the latter decade. This leads to the conclusion of a uniform intensification in the general circulation. The cause thereof is most probably the greater permeability of the atmosphere for short-wave radiations in the decade 1911–1920 (fewer eruptions of ash, etc., by volcanoes).

2. Coincident with the intensification in the general circulation was a rise of about 3° C. in the mean temperature of the land surface and the continental shelves in agreement with the theoretical judgment of A. Defant. On the other hand, the surface of the deep sea probably became generally colder; the increased intermixing of the water surface, which parallels the intensification of the general circulation, is to be viewed as the cause of this.

3. Outside of narrowly limited regions with opposite anomaly, for which an explanation is found in local influences, the amplitude of yearly temperature became greater in the equatorial zone but smaller in the extratropical regions. The condition for the limiting line of this zone is the relation: Yearly oscillation of insolation = yearly oscillation of outward radiation. On account of the heat of vaporization (of water) the width of this equatorial becomes smaller, especially over the seas, in agreement with the facts of observation.

4. Apart from some local exceptions, the phase of the yearly temperature march was retarded in a wide equatorial zone and advanced in the extratropical regions; the limiting line is given by the condition: Mean insolation = mean outward radiation. Here, too, on account of the heat of vaporization the width of this equatorial zone becomes smaller; from observations there are found as the mean latitudes of this limitation the parallels of 35° N. and 32° S.

5. Just as the pressure contrasts have heightened, so have the contrasts in the distribution of precipitation been increased; increased precipitation in the zone of equatorial calms, diminished precipitation in the horse latitudes, and heavier precipitation in the higher latitudes having west wind drift.

The well-outlined relations between the force of the general circulation and the distribution of the several meteorological elements give a very clear and connected picture that is readily understandable from a physical viewpoint. In the study of these results and in the attempt to explain the different attendant phenomena in a consistent physical manner with relation to the general circulation, there arose a series of related problems to which I endeavored to find answers that are at least qualitatively correct. However, there yet remain in the locally limited anomalies different uncertainties in the given explanations, and these leave a more detailed local investigation desirable.

6. A whole series of correlation factors already well known is compared with the indications of the charts, and in by far the greater number of cases confirmation is found. The value of these correlation factors for forecasting purposes appears to rest solely on the fact that the general circulation shows a considerable tendency to maintain its condition.

[1] Geografiska Annaler. 1929. Heft I, pp. 80-82.

7. It appears that both the influence of a changed solar constant and also that of the 11-year sun spot period on the distribution of the meteorological elements over the earth can be explained by uniform oscillations of the general circulation. In this it must be assumed, however, that an increased relative sun spot number as well as an increased solar constant corresponds, as the result of the coincident increase in the turbidity of the atmosphere, to a lessened insolation and so to a diminished intensity of the general circulation.

It would be of interest to investigate how the relations change in the course of the seasons. One of my students has nearly completed a paper relative to this matter and has divided the decades used here into summer, winter, and transition seasons. An additional investigation proposes to set forth the transition from monthly means to the decade means taken as a basis here. For this purpose my assistant, E. Ekhart, is studying the decade 1911–1920—for the present the distribution of pressure and precipitation—and with the use of a considerably greater number of stations he is able to determine what departures from the average conditions here given occur in the individual years. The work will appear in a short time in Abhandlungen des Preuss. Meteorol. Institut. A further investigation, that of lustrum values for 1885–1920, is in view, but for this a great amount of calculating must be done.—*Translated by W. W. Reed.*

City air.—"A sermon in soot," by Arnold H. Kegel, M. D., commissioner of health, Chicago, published in The Aerologist (September, 1929, vol. 5, pp. 5-9, 59, 5 ills.), effectively draws attention to the ever-increasing dustiness of city air and its deleterious effect on health. While smoke abatement has reduced the combustible dust in the air and its tarry content, it has not stemmed the increasing dustiness. Sunshine records of January and February, 1915–16 and 1925–26, show a reduction of 12 per cent, which the author ascribes to the greater air pollution in the later year. The health department's dust observations in Chicago show for 20 stations an average of 124.6 tons of insoluble solid matter per square mile per month in 1925, with an extreme maximum of 460 tons per square mile in the loop district one winter month. The minimum was 13.4 tons at an outlying station in October, November, and December. For a rough comparison the dust tonnages of Pittsburgh, 161; Liverpool, 140; Chicago, 124; St. Louis, 93; and Cincinnati, 73, are presented.

The author believes that Pittsburgh's leading position in pneumonia death rate in 1928 is the result of that city's unenviable extreme dustiness. A dweller in the Loop district, Chicago, would inhale a pound and a half of dust in the course of a year, according to Doctor Kegel's computations. At least in the congested districts provision of washed air indoors, where the city dweller spends most of his time, appears essential as an immediate though only partial health measure, while general electrification of transportation and heating may be the only though remote means of reducing atmospheric pollution.—*C. F. B.*

Attempts to induce rainfall.[1]—The Colony of Hong Kong has suffered from an unprecedented deficiency in rainfall during the 12 months ending June 30, 1929, with consequent distress to the population, owing to water shortage.

Amongst the many suggestions received from the public by the local government was the proposition that powdered kaolin, sprinkled from airplanes above suitable clouds, would induce precipitation; the method was stated to have been employed with sucess in other countries. After discussion with other government officials I made the following recommendation:

> I consider that the experiment might reasonably be attempted once. I have little doubt of its failure, but this avenue of relief may then be considered sufficiently explored and be definitely closed thereafter.

My personal opinion is plainly expressed in the foregoing; had the government refused to countenance the experiment, however, there would have remained a feeling in the public mind that one possible solution of the water problem had not been tried. The experiment was made by the unit of the R. A. F. stationed here, and no precipitation occurred.

The reports in the local press are now being commented upon by journals outside the colony, usually with the implication that this observatory was responsible for the inception and conduct of the experiments. This was not the case; the experiments were authorized by the government to discount any subsequent criticism. No belief in a materially successful result was held by administration or its advisers, including my colleagues and myself.—*C. W. Jeffries.*

Ocean currents the probable cause of the 3-year pressure cycle of the tropical South Pacific.[1]—H. P. Berlage, jr., finds a striking sequence in departures of pressure or temperature across the Pacific Ocean, extending over some months, which he ascribes to the transfer of heat by ocean currents. The region from extreme northern Australia over New Guinea and eastern Java is an active center of high temperature and low pressure, in which the variations in temperature appear to dominate the greater or lesser degree of lowness of the pressure, while immediately outside this active area the pressure variations emanating from the active center dominate the temperature. The compensatory area of high pressure appears to be centered near Easter Island in the eastern South Pacific. The variations in pressure at Port Darwin, representing the Australia-East Indian low, and at Juan Fernandez, in the eastern Pacific high, are practically in opposition, except at the end of the southern winter.

With the changes in pressure at these centers there are corresponding changes in the trade winds and, presumably, in the speeds and temperatures of the ocean currents. There is a well-defined sequence of temperature departures following the extremes of pressure in the north Australian low and the South Pacific high, reaching their maximum phases 2½ months later at Iquique, 4 months later at Malden and Samoa Islands, and 7½ months later at Manila. This progressive sequence is at about 33 miles a day, a rate suggesting strongly the translation of temperature anomalies through the great ocean currents.

There is also a sequence of pressure departures from Juan Fernandez to Port Darwin of one and one-fourth years for the negative departures and one and one-half years for the positive. Furthermore, when the departures at Samoa are the same as at Port Darwin, the temperatures and pressures at Port Darwin hold much the same for some time beyond the period of usual change in the normal 3-year sequence, which is thereby lengthened. The persisting temperature effects of ocean currents seem also to be responsible for the continuance at Port Darwin of plus departures in late winter till midsummer and for the consequent assymetry of the 3-year pressure curve, the fall being more rapid than the

[1] Reprinted from Nature, London, Sept. 28, 1929.

[1] H. P. Berlage, jr., "Uber die Ursache der drei-jahrigen Luftdruckschwankung." Met. Zeits., July, 1929, 46:249–259, 4 figs.

rise. The correspondence or opposition of departures at widely separated stations simultaneously or after an interval of months, as well as the high correlation coefficients, are strongly indicative of successful long-range weather forecasting.—*C. F. B.*

Cool northeastern high ends hot spell.—The excessive hot spell in the northeastern United States the first days of September, 1929, was brought to an early close in New England by the typical development of a high pressure over the St. Lawrence estuary, New Brunswick, Me., and the Gulf of Maine. Over this cool water and near-by land, the pressure rose nearly 0.2 inch from the morning of September 3 to September 4. Half of this rise might have been expected from the movement of the northern tip of the southeastern high eastward, the other half of the pressure rise seems to have been due to the differential temperature of the cool region and the exceedingly hot one close by to the southwest and west. The temperature at Father Point, Quebec, on the south shore of the St. Lawrence estuary, ranged from 46° to 56° F. September 3, while that at Northfield, Vt., ran from 72° to 92° F.

As the northeastern high developed, the cool air ran out from its center westward under the hot southwesterly wind, bringing a welcome relief to most of New England by the morning of September 4. In New Hampshire and southern Maine the cool sea wind running under the hot wind produced a dense, mammillated stratus cloud moving from the SSE. at a (mountain measured) height of about 2,000 feet that lasted throughout the 4th. At night scattered warm-front thunderstorms, probably formed in northern New York and southwestern Quebec, drifted by.

The following day saw the atmospheric structure still more complex, for a slightly cooler north wind set under the now warmer (?) easterly wind from farther (?) out to sea, producing a still lower (1,500 feet) raggedly festooned stratus moving from the east. A light drizzle, increasing toward evening, fell all day in central New Hampshire. Presumably there was a fourfold layer structure to the atmosphere—the cool north wind at the ground, the cool, damp east to southeast wind next above, and the warm southwest and the cooler west to northwest winds at higher altitudes. With clouds at probably four levels, the day was the darkest one in a long time.

September 6 saw the beginning of showery weather, with southerly wind and very low clouds but more changeable sky brightness as the warm front of the oncoming low approached.

One of the unfinished minor projects of the late Dr. C. LeRoy Meisinger was a study of these northeastern highs that ended hot spells in New England so much sooner than in the Middle Atlantic States. An aerological investigation that would show whether, and, if so, how the heated expanded air from the eastern United States drifted northeastward and collected over the cool regions, thereby producing such highs should not only be full of interest but also very helpful in forecasting the termination of the excessive heat.—*Charles F. Brooks.*

Probable origin of the cold wave in India, February, 1929.—During the period January 28–February 3, 1929, an intense cold wave overran the whole of northwest and Central India, where surface temperature went down to about 12° C. below normal, several stations recording the lowest temperature in the last four or five decades. The results of a few soundings over Agra, which reached the stratosphere during and after the passage of the cold wave, appear to throw some light on the origin of the cold air. During winter the normal height of the tropopause over Agra (latitude 27°) is about 14.5 geodynamic kilometers and its temperature is 206° A. (see Doctor Ramanathan's Figure 1, Nature, June 1, p. 834, reproduced on p. 382), while with the invasion of the cold wave the base of the Agra stratosphere came down so low as 11.5 geodynamic kilometers and its temperature rose to 213° A. The conditions in the troposphere and the stratosphere over Agra during the cold wave were similar to those normally found at about latitude 40°. The trajectories of pilot-balloon flights up to 6 kilometers indicate that the cold air came from the northwest. It would thus appear that the cold wave had its origin somewhere to the east of the Caspian Sea.—*S. C. Roy* and *G. Chatterji.*

Droughts in September.—Press reports bring an unusually large number of accounts of drought in various parts of the world. Not since 1893 has Great Britain experienced a more prolonged drought nor has Greenwich recorded a rainless month—as this is likely to be—in 90 years. Farmers are finding the absence of rain very serious. (Daily Telegraph, September 26, 1929.)

The Times, London, of September 18, 1929, reports the long drought at Paris, France, as ended on the 17th. This drought was the second longest since 1873. In 1895, 38 days passed without rain—August 24 to October 2.

From the Fort Dodge, Iowa, Messenger of October 10 it is learned that nearly 6,000 families in Saskatchewan, Canada, will need government aid through the winter. While all of the western Canadian provinces have suffered from lack of rain, Saskatchewan seems to have been the center of the afflicted area.

The Sioux City, Iowa, Journal of October 9, 1929, prints an account from its correspondent in the Argentine, dated Cordoba. In the State of that name little or no rain has fallen in the last six months, the wheat crop is a failure, and unless rain comes within 10 days the corn crop will be in danger. (Subsequent reports, however, show that the rains came on October 22.)

The French daily weather report.[1]—The French Meteorological Service has for some time issued its daily weather report in two parts, the Bulletin Quotidien de Renseignements and the Bulletin Quotidien d'Etudes. The idea of separating the report into two parts, one for general use and one for students of meteorology seems a good one, but the separate purpose of the parts as indicated by their titles has not been fulfilled very clearly in the past. Each part has consisted of four single pages and has contained both tabular matter and charts; the station reports have been divided into two groups, those from French stations being published in the Bulletin Quotidien de Renseignements and those from "foreign" stations in the Bulletin Quotidien d'Etudes.

From July 1, 1929, the form of the report has been altered and it is interesting to note the manner in which General Delcambre, the head of the Office National Météorologique, has endeavored to meet the requirements of the French public, both those seriously interested in meteorology and those whose interest is more superficial. The Bulletin Quotidien de Renseignements has been reduced to a single sheet providing two pages of the same size as those of our own Daily Weather Report, while the Bulletin Quotidien d'Etudes has been expanded to a publication of four sheets, that is, eight single pages. The annual subscription for the latter is 320 francs as against 140 francs for the more modest single sheet of the former.

[1] Reprinted from Meteorological Magazine, August, 1929.

The Bulletin Quotidien de Renseignements in its simplified form contains a 7 a. m. chart for northwest Europe and the eastern Atlantic, on which are entered winds, isobars, and lines showing the change of pressure in the past 24 hours. Beneath this map are forecasts given separately for the region around Paris and for the whole of France. On the reverse side there is a smaller map showing changes of pressure in the past three hours with large arrows indicating the direction of movement of the isallobaric systems; also charts of maximum and minimum temperature and rainfall. The different phases of the système nuageux, of which so much use is made in French forecasting, are indicated on another map which shows the state of the sky at 7 a. m., the regions in which the several types of cloud formation prevail being indicated by distinctive symbols. This report seems admirably to fulfill its purpose of being a simple and (if we except the système nuageux) nontechnical publication.

The Bulletin Quotidien d'Etudes in its new form commences with tables of readings at 7 a. m., 1 p, m., and 6 p. m., for French stations together with aerological reports, while the last page contains a small table of ships' reports from the Atlantic and Mediterranean. It is interesting to note that readings from foreign stations no longer find a place in the report. More than one-half of the eight pages are devoted to charts. In the first of these, which is reproduced as the frontispiece of this number of the magazine, polar fronts appear for the first time in the French daily weather report. The chart is an ambitious one showing isobars and fronts over the whole of that part of the Northern Hemisphere which extends from Europe in the east to eastern Canada, the Great Lakes, and part of the United States in the west. The fronts are shown very clearly, by broken lines for a warm front and a row of black dots for a cold front. Fronts are often difficult to locate; sometimes their very existence is doubtful. Further, they vary greatly in intensity and importance and it therefore seems regrettable that no observations are entered on the chart to help the student to judge of the nature of the fronts and of their effect on the weather in the vicinity. The chart on which these fronts are shown is for 1 p. m. G. M. T. A Northern Hemisphere chart for 1 a. m. covering an area centered at the pole occupies most of the last page of the report, and shows isobars but not fronts.

The importance attached to isallobars in France is shown by the inclusion of six small charts of changes of pressure in the periods of 24 hours, 12 hours and 3 hours respectively, ending at 7 a. m. and again for the same periods ending at 6 p. m. The only forecasts contained in this report are in the form of two charts, one for the anticipated changes of pressure in the 12 hours ending at 7 a. m. the following morning and the other for the state of the sky and the wind anticipated at this hour. Alongside these two charts are written an analysis of the situation and some comments on the reasons which have led to the deductions drawn. The report appears to be issued on the day following that to which it refers, as a short critical discussion is included of the success or otherwise obtained in the forecasts. Such a discussion is likely to be of value by giving the reader an insight into the lines on which the forecasters work, and may in addition be helpful to the forecasters themselves. Curves showing the daily march of temperature both at the summit of the Eiffel Tower and in the courtyard of the Office National Météorologique are also included in a report, the form of which suggests a considerable appetite for meteorological information amongst French students of meteorology.—*J. S. Dines.*

Fire weather investigations in Wisconsin.—Foremost in importance in any plan to grow forest trees is the control of fire, for upon such fire control depends the very existence of the forest. That weather conditions very largely determine the occurrence and severity of forest fires is obvious. Just what the conditions are that spell low or high hazard, however, has never been definitely determined for the Lake States region. To secure this information, a study of fire weather and the hazard resulting was started in the spring of 1928 by the cooperating agencies.

Early in May temporary field stations were established in northeastern Wisconsin in typical jack pine and hardwood areas. At each of these stations during the spring fire season observations were made daily at 8 and 11 a. m. and 2 and 5 p. m. of the conditions prevailing in the open, in the forest, and on partially cut-over areas. The resulting inflammability and moisture content of the litter was also determined at frequent intervals. In addition, the occurrence of fires in the protection districts adjoining the stations was noted and the behavior of going fires observed wherever possible, as was also the character, amount, and distribution of inflammable material typical of the two forest types under observation.

While the data secured have not yet been worked up in detail, a very direct relation between the inflammability of the prevailing forest fire fuels and weather conditions, particularly precipitation and relative humidity is obvious. For example, each of the three critical periods encountered this spring were preceded by from four to eight days without precipitation and with a mid-day humidity of 40 per cent or less. The moisture content of the litter during dry periods also was found to vary directly with the humidity, explaining why fires burn more fiercely between noon and 4 p. m. and are more readily controlled in the morning and late afternoon. Wind velocity was also found to be an important factor when other conditions were favorable for the occurrence of forest fires, velocities of seven miles per hour and over causing fires to spread rapidly and making control difficult.

The spring fire season in northeastern Wisconsin this year (1928) was acute but not abnormal. * * *

The lowest humidity observed was 21 per cent in the open jack-pine country at 5 p. m. on June 6, the last bad fire day of the season. While the humidity tended to run somewhat higher in the hardwood than in the jack-pine country, days with humidity of 30 per cent and less were numerous at both stations. Decidedly higher humidities and a consequent higher moisture content of the litter normally prevailed at the forest stations than in the open in both hardwood and pine, conditions in partially cut-over stands being intermediate. This difference was particularly striking in the hardwood country after the leaves had come out, but also prevailed consistently in jack pine.

On the other hand, light rains were found to be more effective in the open than in the forest, the forest cover evidently preventing the precipitation from reaching the ground. As a result, normal conditions were found to be reversed by light rains, the litter in the forest remaining dry and hence more inflammable than that in the open.

* * * Just what conditions cause fires, apparently dead beyond the possibility of revival, to flare up after lying dormant for days is worth knowing. This spring a fire of this kind occurred in northern Wisconsin in the area that was being covered by this fire-hazard study.

As long as the relative humidity at 8 a. m. was 50 per cent or above the fire remained dormant. However, when the humidity dropped appreciably below 50 per cent

the fire flared up and required determined and sustained effort to keep it under control. Light rainfall did not make the fire safe. A half inch of rain or more seems to be necessary to put a fire in a condition where it is no longer a menace.—*Forestry section, 1927–28, Annual Report of the Director, agricultural experiment station, University of Wisconsin.*

Count Rumford in meteorology.—In the course of a most interesting biography of Count Rumford by Lyman C. Newell, published in Science, July 27, 1928, pages 67–73, the following (pp. 69–70) is of historical interest in American meteorology:

> One of his investigations was an elaborate series of unique experiments on the heat-conducting power of fluids. He showed among many other things that convection currents are the principal means by which heat is transferred through fluids, and described how, when a vessel of water is heated, there is generally an ascending current in the center and a descending current all around the periphery. Hence he concluded it is only when a liquid expands by increase of temperature that a large mass can be readily heated from below. He also pointed out the exceptional behavior of water below 39° F., viz, it contracts when heated and expands when cooled. Then he proceeded to explain how large bodies of water are prevented from freezing at great depths on account of the expansion which takes place on cooling below 39° F., and he mentions as an example that in the Lake of Geneva, at a depth of a thousand feet, the temperature was found to be 40° F. He emphasized the fundamental bearing of this unusual behavior of water on climate everywhere, and on the preservation of trees, fruits, and vegetables during the winter in cold countries.
>
> In his experiments on the heat-conducting power of liquids, Count Rumford * * * turned his conclusions to practical account in making warm clothing, not only of woven fabrics but also of feathers and fur. * * *
>
> In another series of experiments devoted to the radiating power of different surfaces he showed how the power varied with the nature of the surface and illustrated the results by demonstrating the effect of a coating of lampblack in increasing the radiating power of a body.
>
> He also investigated the absorption of heat by different surfaces. His results led to the law that good radiators are good absorbers and the recommendation that vessels in which water is to be heated should be blackened on the outside. In speculating on the function of the coloring matter in the skin of the negro, he said:
>
> "Were I called to inhabit a very hot country, nothing should prevent me from making the experiment of blackening my skin, or, at least, of wearing a black shirt, in the shade and especially at night, in order to find out if by those means I could contrive to make myself more comfortable."
>
> —*C. F. B.*

New rainfall record for Canal Zone.—Rainfall in this consular district during the months of July, August, and September was considerably greater than during the corresponding months of the year 1928. A notable feature was a precipitation in the space of one hour of 5.16 inches.

The total rainfall in the Colon consular district during the month of August was 23.78 inches.

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SOLAR OBSERVATIONS

SOLAR AND SKY RADIATION MEASUREMENTS DURING SEPTEMBER, 1929

By HERBERT H. KIMBALL, Solar Radiation Investigations

For a description of instruments and exposures and an account of the method of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1929, 57: 26.

Table 1 shows that solar radiation intensities averaged below the normal values for September at Madison, Wis., and close to normal at Washington, D. C., and Lincoln, Nebr.

Table 2 shows an excess in the total solar radiation (direct + diffuse) received on a horizontal surface at Washington and Madison, and a decided deficiency at Lincoln, Chicago, and New York.

Skylight polarization measurements obtained on five days at Washington give a mean of 51 per cent and a maximum of 56 per cent on the 24th. At Madison, measurements obtained on seven days give a mean of 50 per cent and a maximum of 69 per cent on the 18th. The values obtained at both stations are below the September averages for the respective stations.

TABLE 1.—*Solar radiation intensities during September, 1929*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M. 5.0	4.0	3.0	2.0	[1] 1.0	P. M. 2.0	3.0	4.0	5.0	Local mean solar time
	e.										e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Sept. 3	13.13						0.71	0.55			13.13
Sept. 7	19.89					1.09					19.23
Sept. 9	19.23			0.81	0.93						19.23
Sept. 10	16.79			0.86	1.02						17.96
Sept. 11	9.14				1.18	1.42					7.87
Sept. 12	8.18				1.11						9.83
Sept. 18	8.81						1.24				7.29
Sept. 19	4.57	0.86	0.98	1.11	1.30	1.50					4.37
Sept. 21	6.27			0.72							5.79
Sept. 24	8.81	0.77	0.89	1.03	1.18	1.33	1.06	0.91	0.75	0.62	5.36
Means		(0.82)	(0.94)	0.91	1.12	1.34	1.00	(0.73)	(0.75)	(0.62)	
Departures		+0.12	+0.19	+0.03	+0.07	+0.01	−0.05	+0.12	−0.02	−0.04	
Madison, Wis.											
Sept. 3	15.11			0.44	0.63	0.90					14.60
Sept. 11	6.76		0.91	1.02	1.19	1.29					7.04
Sept. 14	6.27		0.99	1.11	1.25	1.40					5.36
Sept. 17	6.27				1.27	1.49					4.37
Sept. 18	4.95		0.95	1.14	1.31	1.51	1.27				5.36
Sept. 21	7.04			0.78	1.02						6.76
Sept. 23	6.76		0.57	0.73	0.97	1.28	1.08				8.18
Sept. 26	8.48				0.78						12.24
Means			0.86	0.87	1.05	1.31	(1.18)				
Departures			−0.05	−0.15	−0.11	−0.06	+0.02				
Lincoln, Nebr.											
Sept. 13	10.59			1.04	1.26						9.14
Sept. 14	7.29		0.97	1.09	1.28	1.48			1.03	0.86	7.04
Sept. 16	7.29			1.00	1.14						6.27
Sept. 17	7.87		0.71	0.98	1.13	1.36	1.09	0.91	0.76	0.62	7.29
Sept. 23	11.38						0.84	0.70	0.64		10.21
Sept. 24	10.59						0.94				10.21
Sept. 26	12.68							0.74			13.13
Means			(0.84)	1.03	1.20	(1.42)	0.96	0.78	0.81	(0.74)	
Departures			−0.03	+0.02	+0.01	+0.02	−0.19	−0.19	−0.02	+0.01	

[1] Extrapolated.

TABLE 2.—*Solar and sky radiation received on a horizontal surface*

[Gram-calories per square centimeter of horizontal surface]

Week beginning	Average daily radiation: Washington	Madison	Lincoln	Chicago	New York	Fresno	La Jolla	Average daily departure from normal: Washington	Madison	Lincoln	Chicago	New York
1929	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Sept. 3	369	314	274	296	182	582	254	−7	−52	−150	−19	−124
Sept. 10	361	338	436	297	281	529	205	−13	−4	+29	+13	−14
Sept. 17	400	437	360	281	288	425	265	+49	+98	−23	+14	+13
Sept. 24	402	267	305	149	202	490	417	+62	−23	−35	−84	−55
Excess or deficiency since first of year on Sept. 30								+5,789	−539	−3,303	−973	−5,369

REFLECTIVITY OF DIFFERENT KINDS OF SURFACES—A CORRECTION

Dr. L. F. Richardson invites our attention to an error in our paper on the above subject in the REVIEW for July of the current volume, page 291, as follows:

"There is a definite mistake in line 25 from the beginning. You state that 'A_s' is the area of the window. Unfortunately this is hardly even roughly true. There is no short name for A_s. It is not a solid angle. It is the rather complicated idea explained in paragraph 5 (1) of the Prague report.[1]

"Perhaps the best short explanation would be to say $\frac{A_s}{A_G}=\left(\frac{\sin\ \alpha_s}{\sin\ \alpha_G}\right)^2$ where α_G is the semi-vertical angle of a cone having its vertex at the midpoint of the edge of the white wedge and bounded by the iris and where α_s is a similar angle for the sky window."

The reader is referred to the paper by Richardson, above cited, for further details.—*H. H. K. and I. F. H.*

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. C. S. Freeman, Superintendent U. S. Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, and Mount Wilson observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time	Heliographic: Diff. long.	Longitude	Latitude	Area: Spot	Group	Total area for each day
1929	h. m.	°	°	°			
Sept. 1 (Naval Observatory).	12 5	−18.0	282.9	−12.5		15	
		−10.0	290.9	+4.5		6	21
Sept. 2 (Naval Observatory).	10 50	−4.0	284.4	−13.0		18	
		+3.5	291.9	+5.0		12	30
Sept. 3 (Naval Observatory)	10 45	−79.0	196.2	+21.5	93		
		−45.5	220.7	+12.5	6		
		−14.0	261.2	−24.5		9	
		+11.5	286.7	−11.0		15	
		+16.0	291.2	+5.0	6		129
Sept. 4 (Naval Observatory).	11 6	−65.5	196.3	+21.0	77		
		−43.5	218.3	+10.0	9		
		+2.5	264.3	−5.5	12		
		+30.0	291.8	+4.5	3		101
Sept. 5 (Naval Observatory).	11 49	−81.5	166.7	−10.0	154		
		−53.0	195.2	+20.5	62		
		−28.5	219.7	+12.5	3		
		−15.0	233.2	+17.2	3		
		+15.0	263.2	−5.0		216	438
Sept. 6 (Naval Observatory).	14 6	−67.0	166.8	−10.5	62		
		−39.0	194.8	+20.5	56		
		+7.5	241.3	−13.5		12	
		+30.5	264.3	−5.0		216	346

[1] Richardson, L. F., 1928. Report on photometers for a survey of the reflectivity of the earth's surface. Union Géodésique et Géophysique Internationale, Section de Météorologie. Troisième Assemblée Générale: Prague, 1927.

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1929	h. m.	°	°	°			
Sept. 7 (Naval Observatory).	10 37	−55.0	167.5	−9.5	46		
		−27.5	195.0	+21.0	40		
		−5.0	217.5	+13.5		3	
		+19.5	242.0	−13.0		6	
		+42.0	264.5	−5.0		201	
		+50.5	273.0	+10.0		46	342
Sept. 8 (Naval Observatory).	10 41	−48.5	160.8	−6.0	6		
		−42.0	167.3	−10.0	34		
		−38.0	171.3	−3.5	3		
		−14.5	194.8	+20.5	40		
		+9.5	218.8	+13.5		25	
		+14.0	223.3	+2.0		6	
		+54.5	263.8	−5.0		170	
		+65.5	274.8	+9.0		28	312
Sept. 9 (Naval Observatory).	12 15	−33.5	161.7	−6.5	6		
		−28.0	167.2	−10.5		40	
		−22.0	173.2	+15.5	6		
		−1.0	194.2	+20.5	46		
		+22.5	217.7	+13.5		15	
		+69.0	264.2	−4.5		154	
		+80.5	275.7	+10.0	15		282
Sept. 10 (Naval Observatory).	11 20	−76.0	106.5	+5.5	62		
		−44.0	138.5	+23.0	6		
		−20.5	162.0	−6.0		12	
		−15.0	167.5	−10.0	12		
		−8.0	174.5	+15.0	6		
		+11.5	194.0	+21.0	31		
		+82.5	265.0	−4.0		139	268
Sept. 11 (Naval Observatory).	11 0	−63.0	106.5	+5.0	31		
		−2.0	167.5	−10.0	15		
		+24.0	193.5	+21.0	25		71
Sept. 12 (Naval Observatory).	10 52	−73.5	82.8	+15.5	15		
		−44.0	112.3	+5.0		62	
		−38.5	117.8	+38.5	3		
		+10.5	166.8	−10.5		9	
		+19.5	175.8	+16.0		18	
		+33.0	189.3	−16.0	3		
		+37.5	193.8	+21.0	18		
		+61.0	217.3	+5.0		6	134
Sept. 13 (Naval Observatory).	10 51	−86.5	56.6	−7.0	123		
		−59.0	84.1	+15.5	6		
		−31.5	111.6	+5.0		46	
		+25.0	168.1	−10.0	6		
		+32.5	175.6	+16.0		31	
		+51.0	194.1	+21.0	15		
		+77.0	220.1	+5.5	15		242
Sept. 14 (Naval Observatory).	10 38	−73.0	57.1	−8.0	62		
		−18.0	112.1	+4.5		9	
		+47.0	177.1	+15.5		9	80
Sept 15 (Naval Observatory).	11 18	−58.5	58.0	−7.5	68		
		−9.0	107.5	+5.5		25	
		+17.0	133.5	+20.0	3		
		+59.5	176.0	+15.5		31	127
Sept.16 (Naval Observatory).	10 39	−80.0	23.6	−21.0	185		
		−46.0	57.6	−8.0	49		
		+8.5	112.1	+5.0		46	
		+51.5	155.1	+4.0	6		
		+72.5	176.1	+15.5		108	394
Sept. 18 (Naval Observatory).	11 1	−52.5	24.5	−21.0		154	
		−19.0	58.0	−8.0	46		200
Sept. 19 (Naval Observatory).	11 1	−39.5	24.3	−21.0		154	
		−6.0	57.8	−8.0	31		
		+25.0	88.8	+21.0	6		191
Sept. 20 (Naval Observatory).	10 40	−26.0	24.8	−21.0	154		
		+7.0	57.8	−8.0	22		
		+37.0	87.8	+21.0		37	
		+45.5	96.3	−14.0		62	275

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
	h. m.	°	°	°			
Sept. 21 (Naval Observatory).	10 26	−27.0	10.8	+3.0		12	
		−26.5	11.3	−25.0		46	
		−13.0	24.8	−21.0	139		
		+3.0	40.8	−22.0	3		
		+20.5	58.3	−8.0	12		
		+50.5	88.3	+21.0		25	
		+59.5	97.3	−14.0		93	330
Sept. 22 (Harvard)	15 25	−9.0	13.0	−27.5	34		
		+6.0	28.0	−20.5	211		
		+75.5	97.5	−14.5		133	378
Sept. 23 (Naval Observatory).	12 10	+14.0	24.4	−21.5		154	
		+23.5	33.9	+9.5	3		
		+32.0	42.4	−12.0	6		163
Sept. 24 (Naval Observatory).	10 52	+17.5	15.4	+5.5	3		
		+26.5	24.4	−21.5		108	
		+46.5	44.4	+17.5	3		114
Sept. 25 (Naval Observatory).	10 33	+38.5	23.4	−22.0		52	52
Sept. 26 (Naval Observatory).	10 40	−68.0	263.6	+14.0	9		
		−57.0	274.6	+9.0		31	
		+53.5	25.1	−22.0	25		65
Sept. 27 (Naval Observatory).	10 33	−56.5	262.0	+12.0	9		
		−42.5	276.0	+9.0		46	
		−18.0	300.5	−9.0	3		58
Sept. 28 (Naval Observatory).	10 48	−86.0	219.2	+11.5	46		
		−41.5	263.7	+12.5	6		
		−29.0	276.2	+9.5		108	160
Sept. 29 (Naval Observatory).	10 38	−75.0	217.1	+11.5		62	
		−27.0	265.1	+12.5		6	
		−14.5	277.6	+10.0		123	191
Sept. 30 (Mount Wilson).	13 30	−60.0	217.3	+12.0		104	
		0.0	277.3	+11.0		254	358
Mean daily area for September							202

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR SEPTEMBER, 1929 [1]

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich, Switzerland]

September, 1929	Relative numbers	September, 1929	Relative numbers	September, 1929	Relative numbers
1	9	11	39	21	55
2	17	12	31	22	[2] 44
3	31	13	53	23	35
4	28	14	25	24	13
5	[3] M 49	15	32	25	10
6	49	16	26	26	[3] E 23
7	[3] M 62	17	[4] 38	27	25
8	54	18	17	28	17
9	58	19	20	29	[4] 43
10	56	20	[3] W 43	30	[2] 40

Mean, 30 days=34.7.

[1] Dependent alone on observations at Zurich and its station at Arosa.
[2]=Passage of an averaged-sized group through the central meridian.
[3]=New formation of a large or average-sized center of activity: E, on the eastern part of the sun's disk; W, on the western part; M, in the central zone.
[4]=Entrance of a large or average-sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

By RICHMOND T. ZOCH

Free-air temperatures were below normal at practically all levels at all of the aerological stations. (See Table 1.)

Free-air relative humidity departures were variable at all stations excepting Due West, where there was a pronounced positive departure. This is significant in that the total precipitation for the month at this station was the greatest ever recorded. Vapor pressure departures were mostly below normal except at Due West.

The resultant winds had a southerly component at all levels over the western and eastern parts of the country. (See Table 3.) Over the northern part of the country and over the Mississippi Valley the resultant winds had a northerly component.

Table 2 gives a summary of observations made at naval air stations. Those made at Washington, D. C., were formerly incorporated in Table 1, but as these data are now being computed by the naval air stations, they have been placed in a separate table. It should be noted there is close agreement between the free-air temperatures and relative humidities computed by the Weather Bureau and those computed by the naval air stations.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during September, 1929*

TEMPERATURE (° C.)

Altitude meters m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)		Washington, D. C. (naval air station) (7 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	22.4	−0.8	22.0	−1.2	14.3	+0.1	22.1	−2.0	17.2	−3.0	------	------
500	21.0	−0.6	19.4	−1.2	14.1	−0.3	21.8	−0.4	15.4	−2.8	------	------
1,000	18.8	−0.4	16.8	−1.2	10.3	−2.6	19.8	+0.1	12.1	−3.1	------	------
1,500	16.4	−0.1	15.0	−0.6	8.0	−2.9	16.7	−0.7	9.9	−2.4	------	------
2,000	13.3	−0.9	13.0	−0.1	5.3	−3.1	13.6	−1.4	7.6	−2.1	------	------
2,500	9.6	−1.8	10.4	+0.1	2.6	−2.9	10.9	−1.7	5.5	−1.5	------	------
3,000	6.3	−2.2	7.5	−0.1	0.1	−2.4	7.9	−2.2	2.9	−1.7	------	------
4,000	------	------	------	------	−5.8	−2.8	------	------	−3.1	−2.6	------	------

RELATIVE HUMIDITY (%)

Surface	66	−2	76	+8	56	−12	78	+2	67	−1	------	------
500	61	−2	78	+7	56	−10	71	−5	67	0	------	------
1,000	62	−1	80	+9	60	0	65	−6	70	+4	------	------
1,500	61	+1	79	+7	59	+1	64	−1	62	−2	------	------
2,000	64	+9	77	+9	57	+5	63	+3	60	+1	------	------
2,500	66	+15	74	+8	60	+8	60	+6	52	−1	------	------
3,000	91	+43	71	+9	66	+15	57	+7	49	−3	------	------
4,000	------	------	------	------	52	+6	------	------	42	−3	------	------

VAPOR PRESSURE (*mb.*)

Surface	17.65	−1.76	20.45	+1.05	9.35	−2.00	20.80	−2.00	13.47	−2.85	------	------
500	15.85	−1.50	18.12	+0.87	9.18	−1.92	18.36	−1.94	12.25	−2.18	------	------
1,000	13.43	−0.92	15.96	+1.19	7.73	−1.36	14.89	−1.32	10.35	−1.66	------	------
1,500	11.30	−0.34	13.87	+1.05	6.42	−0.86	12.05	−0.63	7.98	−1.75	------	------
2,000	9.83	+0.93	11.79	+1.22	5.11	−0.83	9.33	−0.54	6.73	−0.85	------	------
2,500	8.08	+1.41	9.96	+1.17	4.44	−0.47	7.12	−0.42	4.61	−1.27	------	------
3,000	8.07	+3.06	8.60	+1.16	3.92	−0.20	5.46	−0.43	3.78	−0.67	------	------
4,000	------	------	------	------	1.98	−0.70	------	------	2.79	+0.42	------	------

TABLE 2.—*Free-air data determined at naval air stations during September, 1929*

Altitude meters m. s. l.	Temperature (° C.)			Relative humidity (%)		
	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.
Surface	22.8	21.3	19.7	86	73	72
500	21.9	18.5	17.9	81	80	61
1,000	20.2	20.0	16.2	74	57	56
2,000	15.3	17.5	12.0	63	34	56
3,000	9.9	----------	8.3	50	----------	50
4,000	6.6	----------	7.8	32	----------	33
5,000	----------	----------	4.2	----------	----------	26

TABLE 3.—*Observations by means of kites, captive and limited-height sounding balloons during September, 1929*

	Broken Arrow, Okla.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
Mean altitudes (meters) m. s. l. reached during month	2,201	2,060	2,753	2,006	2,640
Maximum altitude (meters) m. s. l. reached and date	[1] 3,271	[2] 3,878	[3] 4,520	[4] 3,815	[4] 4,875
Number of flights made	32	24	25	23	23
Number of days on which flights were made	28	23	23	22	21

[1] 15th. [2] 14th. [3] 10th. [4] 30th.

In addition to the above there are approximately 120 pilot balloon observations made daily at 50 Weather Bureau stations in the United States.

TABLE 4.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during September, 1929*

Altitude m. s. l.	Broken Arrow, Okla. (233 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,868 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (65 meters)		Key West, Fla. (11 meters)		Los Angeles, Calif. (40 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Meters	°		°		°		°		°		°		°		°		°		°	
Surface	S 11 E	1.2	S 18 W	2.0	N 76 W	2.9	N 44 E	2.3	N 58 W	1.0	N 85 E	0.4	S 88 W	0.7	N 78 E	1.4	S 81 E	1.3	N 88 W	1.2
500	S 4 W	5.6	S 40 W	2.9	----------	-----	N 69 E	4.5	N 61 W	1.3	S 5 E	3.5	----------	-----	S 69 E	4.5	S 58 E	3.1	S 80 E	1.2
1,000	S 29 W	6.5	N 73 W	3.8	----------	-----	N 75 E	3.7	N 26 W	2.6	S 6 E	3.5	N 89 W	3.0	S 48 E	4.7	S 51 E	3.4	S 62 E	1.8
1,500	S 51 W	4.7	N 43 W	3.5	----------	-----	N 51 E	1.3	N 44 W	4.2	S 55 E	3.1	N 61 W	4.2	S 36 E	4.9	S 37 E	3.0	S 75 E	1.7
2,000	S 70 W	4.3	N 61 W	4.8	N 88 W	4.5	N 76 W	1.3	N 60 W	6.1	E	2.8	N 56 W	5.5	S 39 E	4.2	S 39 E	3.7	S 22 E	1.9
2,500	N 83 W	3.8	N 64 W	5.3	S 89 W	5.6	S 71 W	1.9	N 76 W	7.6	N 71 E	2.9	N 60 W	6.1	S 38 E	4.8	S 48 E	3.2	S 7 W	2.1
3,000	N 49 W	2.7	S 88 W	7.5	N 81 W	6.6	S 61 W	2.8	N 84 W	10.0	N 82 E	2.4	N 66 W	7.1	S 18 E	2.9	S 49 E	2.0	S 32 W	2.6
4,000	N 5 W	2.4	----------	-----	N 81 W	6.6	S 68 W	3.4	N 86 W	12.4	----------	-----	N 66 W	7.1	S 13 E	2.7	S 79 E	1.6	S 6 W	2.4
5,000	N 14 W	4.1	----------	-----	S 75 W	6.4	S 58 W	3.8	----------	-----	----------	-----	N 61 W	9.5	S 9 E	1.4	S 63 E	1.4	----------	-----

Altitude m. s. l.	Medford, Oreg. (446 meters)		Memphis, Tenn. (145 meters)		New Orleans, La. (25 meters)		Omaha, Nebr. (313 meters)		Royal Center, Ind. (225 meters)		Salt Lake City, Utah (1,280 meters)		San Francisco, Calif. (60 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (67 meters)		Washington, D. C. (34 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Meters	°		°		°		°		°		°		°		°		°		°	
Surface	S 26 E	1.6	N 83 E	1.9	N 46 E	1.6	S 51 E	1.1	S 60 E	1.0	S 25 E	2.8	N 52 W	0.3	S 64 E	0.5	S 84 E	1.0	N 21 E	0.7
500	S 34 E	1.1	S 53 E	3.3	S 87 E	4.8	S 7 E	3.1	S 55 E	2.5	----------	-----	S 67 W	1.6	S 45 W	2.1	N 1 W	0.5	N 14 E	2.4
1,000	N 4 E	0.1	N 45 W	0.1	S 84 E	3.7	S 33 W	6.9	S 55 W	2.8	----------	-----	N 61 W	3.6	S 82 W	5.3	N 12 E	2.3	N 20 W	2.1
1,500	S 85 E	1.6	N 51 W	1.0	S 86 E	3.3	S 55 W	6.0	S 62 W	4.0	S 19 E	4.4	N 75 W	2.0	S 85 W	5.7	N 27 E	3.8	N 48 W	2.1
2,000	N 71 E	1.4	N 45 W	1.6	N 76 E	2.8	S 77 W	6.3	S 63 W	4.4	S 2 E	4.9	S 61 W	1.0	S 79 W	6.8	N 61 E	4.0	N 87 W	1.5
2,500	N 39 W	1.2	N 13 E	0.8	N 65 E	3.3	S 71 W	6.7	S 80 W	5.5	S 19 W	4.0	S 21 W	0.9	S 72 W	8.5	----------	-----	S 82 W	2.6
3,000	N 61 W	2.4	N 9 W	4.0	N 60 E	3.3	S 77 W	6.7	S 78 W	5.8	S 58 W	4.3	N 57 W	3.4	S 72 W	8.2	----------	-----	S 66 W	2.0
4,000	N 47 W	3.6	----------	-----	N 30 E	2.4	S 79 W	9.5	S 84 W	7.9	S 73 W	6.5	----------	-----	S 79 W	8.7	----------	-----	----------	-----
5,000	N 33 W	6.2	----------	-----	N 13 E	3.2	----------	-----	S 61 W	5.7	S 70 W	9.8	----------	-----	N 74 W	10.6	----------	-----	----------	-----

WEATHER IN THE UNITED STATES

THE WEATHER ELEMENTS

By P. C. DAY

GENERAL SUMMARY

The important features of the weather of the month were the high temperatures experienced during the first few days over the greater part of the country from the Rocky Mountains eastward, the severe drought that existed at the end over the far Northwest, and the important tropical storm that threatened the coast districts of southern Florida during the last few days, which fortunately passed around the southern end of the peninsula and across the western part of the mainland and into Georgia and to the northeastward during the first few days of October. No important loss of life occurred during the passage of this storm and the damage to property from wind was mainly small, though considerable damage to crops and property was sustained on account of heavy rains and floods in some of the districts within the area of its influence.

PRESSURE AND WINDS

The first indication of a break in the severe drought that had prevailed during much of the latter part of the summer over the greater part of the country appeared on the morning of September 3, when a cyclonic storm of moderate proportions was central over the Dakotas, attended by general, but only moderate precipitation over much of the Rocky Mountain area and into the northern Plains States. At the same time, local, heavy rains had occurred along the Gulf and South Atlantic coasts. During the 4th the storm area in the Northwest had extended eastward into the central Plains and to near the upper Mississippi Valley and northward into the adjacent Canadian Provinces with some increase in the rate of precipitation, and rains continued in the Gulf and South Atlantic coast regions, the falls becoming heavy locally in western Florida and the rains extending into the southern Appalachian region, though here they were mainly light.

By the morning of the 5th the northwestern disturbance had largely moved into the adjacent Canadian Provinces, but rains still continued over a considerable area from the northern portions of Texas and Louisiana northeastward to the upper Lakes, the falls being fairly generous in many portions of this area. At the same time, precipitation continued along the South Atlantic coast and had extended northward to the Chesapeake Bay region, with local, heavy falls near the coast from Florida to North Carolina. By the following morning the cyclonic conditions, existing during the preceding few days, had largely dissipated though local, heavy rains still persisted over portions of the middle Atlantic coast, in the lower Ohio and middle Mississippi Valleys and portions of the Lake region, and at scattered points in the Great Plains and portions of the Rocky Mountains where rain had changed to snow.

At the morning observation of the 7th anticyclonic conditions existed over the central valleys, but precipitation had persisted in widely scattered areas, frequent light thunderstorms occurring in the Southeastern States and extending into the Ohio Valley and portions of the lower Lake region, these conditions continuing over many eastern districts during the following day, with the precipitation area becoming better defined in the southern portions of the Plains and Rocky Mountain regions.

By the morning of the 9th a well-defined cyclone had developed over Iowa and heavy rains had fallen over near-by areas, effectually ending the drought over many localities which had been only partially relieved by the showers during the earlier part of the month. The cyclone had extended to the northward of Lake Superior by the morning of the 10th and further rains occurred over many districts from the upper Mississippi Valley to the Lake region, extending eastward to the New England coast, while scattered rains were reported from the Ohio Valley and portions of the Gulf States. Some heavy local rains were reported the following morning from points in Texas and the lower Mississippi Valley and showers continued near the Appalachian Mountains from northern Alabama to New England, but in most western districts fair weather had prevailed for several days.

At the 8 a. m. observation of the 13th a cyclonic storm that had advanced southeastward from central-western Canada without important precipitation became more active, and rain had occurred during the preceding 24 hours over an extensive area from the eastern Plains to the Great Lakes and southward over the Ohio and Mississippi Valleys to near the Gulf coast, heavy rains occurring in portions of Louisiana, the western parts of Tennessee and Kentucky, and in near-by areas. By the following day the rain area had extended eastward to the Altantic coast, heavy falls occurring at numerous points in the more eastern districts. On the following day, precipitation occurred over the districts near the Atlantic coast, but elsewhere the weather very generally cleared and but little precipitation occurred during the following two days except rain was rather general, but mainly light, on the 17th over many eastern districts except near the Atlantic coast, and on the following day along the immediate Atlantic coast.

From the 19th to the 24th there was little precipitation in any part of the country, but on the latter date considerable rain occurred in the far Northwest and also in the Southeast. By the following morning the weather had largely cleared over the Northwest, but rain continued over the Southeast where there were signs of a tropical disturbance in the vicinity of the Bahama Islands, which, during the following few days, advanced slowly to the southwestward, reaching the vicinity of the southern end of the Florida Peninsula by the morning of the 28th. During the following 24 hours it passed between Key West and the mainland moving northwesterly toward Pensacola. It reached the vicinity of the latter place by the morning of the 30th where it changed its course to the northeast, passing the vicinity of Thomasville, Ga., by the morning of October 1 and thence continuing its course northeastward near the coast during the next few days. This storm was attended by the usual hurricane winds and heavy rains near its center, and unusually heavy rains occurred in portions of Florida, Georgia, and the Carolinas and to a lesser extent along the coast in more northern districts.

Anticyclones dominated, to some extent, the more northern districts, particularly the Northeastern States during the latter part of the second and much of the last decade, but no important changes in weather conditions resulted therefrom.

The winds of the month were not severe over any extensive area, though during the passage of the hurricane over some of the coast districts of Florida and to the

northeastward high winds were recorded, but on account of the precautionary measures adopted only a few lives were lost and no extensive damage to property resulted. A few tornadoes occurred, but only one life was lost thereby, though 25 persons lost their lives by the sinking of a boat in a gale on Lake Michigan.

The average atmospheric pressure was moderately higher than normal over all northern districts and to a considerable extent over the southeastern districts. Over the Gulf States and from Texas northwestward to central Washington and thence west to the Pacific averages of pressure were slightly less than normal. Compared with the preceding August, pressures were higher over all northern and most central districts, but were lower to the southward.

TEMPERATURE

The month was marked by much cool weather in the central and north-central portions, especially over the northern and middle divisions of the Plains and Rocky Mountain regions. A period of widespread heat during the first week was another noteworthy feature.

The opening of the month found high temperatures prevailing in the Eastern and Central States north of the Cotton Region. In the Northeast, with the lower Lake region and most of the Ohio Valley, the weather continued mainly hot during the first decade, though after the 4th temperatures usually were not so high as before. In Minnesota and all but the southernmost portions of the Plains and the Mountain regions the middle and later portions of this decade were unseasonably cool. The transition from heat to cold was an abrupt one over the Dakotas and adjacent districts, Bismarck recording 102° on the 1st and 32° on the 6th.

From the 10th to the 17th warmth prevailed in the far West, also mainly in the Atlantic and Gulf States, but most districts between the Rocky Mountains and the Appalachians were considerably cooler than normal.

About the 17th marked heat prevailed over large portions of California and Nevada, with a strong east wind bringing temperatures in the nineties about the hour of sunrise to some southern coast cities of California, where normally even the afternoon marks of September are in the seventies or low in the eighties. This strong east wind was probably due to the effect of a well-defined hurricane passing up the coast from the vicinity of lower California.

From the 17th to the 24th cool weather prevailed nearly everywhere east of the Rocky Mountains and in the far Northwest besides. Particularly cool weather for the season prevailed in the Lake region and the Northeast.

The closing week was notably cool in the far Northwest, but from Arizona and Utah eastward and northeastward it was practically everywhere warmer than normal.

The month averaged cooler than normal over most of the central and western thirds of the country, also over a portion of the Southeast. In a record covering about 60 years at Cheyenne, Wyo., it was the coolest September, save one. Generally in Montana and the Dakotas, Nebraska, and eastern Wyoming the monthly temperatures averaged 4° to 6° below normal.

In the Pacific Northwest the month averaged warmer than normal, and generally from California to the middle Gulf region it was a trifle warmer than normal. In the Northeastern States there was a moderate excess, reaching 3° to 4° at points in interior New York.

The highest marks were usually recorded during the opening week, save in Idaho, Nevada, and the Pacific States about the middle of the month. The very highest was 117° in southern interior California on the 13th. East of the Rocky Mountains 110° was reported from Nebraska and South Dakota on the 1st and 2d.

Over the eastern half of the country the lowest marks were reached from the 17th to the 21st. The southern plains were coolest on the 10th, and several parts of the far West during the last few days of the month. The lowest of all reported readings was 12°, which occurred in four States on four different dates from the 7th to 27th.

The killing frosts in parts of Minnesota and the upper Lake region about the 18th were earlier than usual and ended a short growing season.

PRECIPITATION

There was decidedly heavy rainfall over most southeastern districts, while the northern plains and the Rocky Mountain area had nearly always considerable amounts for the season. For the country, as a whole, the month's precipitation was poorly distributed, both over the surface and in time of fall.

In Florida the average precipitation was larger than in any other State, being almost 11 inches. Fellsmere Station, in the central part of the State, measured 25.15 inches. In northern and eastern Georgia and the western portions of the Carolinas the totals were large, and generally the rainfall exceeded the normal as far west as central Louisiana and as far northwest as the lower and middle Ohio River. Part of eastern North Carolina had a marked excess, while in Virginia and to northeastward the distribution was uneven, the most notable region here of large falls extending from northeastern Maryland to southeastern New York. In the vicinity of New Orleans excessive precipitation occurred on the 6th and 7th, when 10.75 inches fell in less than 24 hours, the greatest amount ever recorded for that period of time in September.

From western Pennsylvania to central Illinois and in lower Michigan and eastern Wisconsin the rainfall was mainly deficient, frequently to the extent of 60 or 70 per cent.

West of the Mississippi River considerable deficiencies were reported from central and southeastern Texas, eastern Kansas, and the Pacific Northwest.

In California a peculiar situation was noted. The northern third of the State was practically without precipitation and the central portion had almost wholly small falls. In southern California, especially the interior portion, there were unusually large falls for the time of year, and large amounts fell farther eastward and northeastward to north-central New Mexico.

In the far Northwest the month was notably dry, Oregon reporting the least of September record in the climatological history of the State, and similar conditions existed in Washington, which had the least precipitation save in one year. The combined precipitation in both States for the three months, July to September, 1929, inclusive, was the least of record for those months.

SNOWFALL

Over most of Wyoming and considerable portions of adjoining States the snowfall was large for the time of year, notably about the 6th and 7th. However, few serious consequences came from this snow. In the high mountains of the Pacific and Plateau States a few light falls were noted.

RELATIVE HUMIDITY

There were large excesses in the average percentages of relative humidity, as compared with the normal, in most of the mountain and southern plateau States, where the positive departures ranged from 10 to 20 per cent; there were excesses also from the Ohio Valley southward and southeastward to the Gulf and South Atlantic States. In other districts the averages were mainly below normal, the deficiencies being large in the far Northwest.

SEVERE LOCAL STORMS, SEPTEMBER, 1929

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the annual report of the chief of bureau]

Place	Date	Time	Width of path, yards [1]	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Fergus and Wheatland, Mont.	1					Hail	Considerable crop destruction	Official, U. S. Weather Bureau.
Toole and Hill, Mont	2					do	do	Do.
Paducah, Tex	4	3 p. m	440		$2,500	do	Crops damaged and poultry killed or injured	Do.
Rankin, Tex	4	5.40 p. m	4 mi.		4,000	Hail and wind	Buildings unroofed and otherwise damaged by wind.	Do.
Littlefield, Tex	4	7 p. m	10 mi.			do	Crops considerably injured	Do.
Liberty, Mont	4					Hail	Crops damaged	Do.
Plainview, Tex	5	8 p. m	1,760		25,000	do	do	Do.
Spur, Tex	5	8 p. m	2,640		10,000	do	do	Do.
Crosbyton, Tex	5	10 p. m	3 mi.			do	Buildings and crops damaged	Do.
Anadarko, Okla	8	5 p. m	6 mi.		100,000	Wind and rain	Severe damage to property and crops	Do.
Kingston, Okla	8	5 p. m				Hail	Chief damage to crops; minor property damage	Do.
Fort Stockton, Tex	8	5–7 p. m	5 mi.		50,000	Wind	Much damage to property; 1 person injured	Do.
Chickasha, Okla. (4 miles southwest of).	8	7–8 p. m	1,760		33,000	do	Damage chiefly to property other than crops	Do.
Chickasha, Okla. (northwest of).	8	8 p. m	1,320			Hail	Crops and buildings damaged	Do.
Norman, Okla. (near)	8	9.15 p. m	1,760		25,000	Wind	Airport and 2 planes damaged; 2 planes demolished; minor crop injury; 1 person injured.	Do.
Stonewall, Okla. (near)	8	10 p. m				Wind and hail	Crops badly damaged; 4 persons injured	Do.
Monroe, Wapello, and Delaware Counties, Iowa.	8	P. m			63,000	do	Character of damage not reported	Do.
Pennsylvania (southeastern).	8			1	100,000	Wind, rain, and electrical.	Several barns destroyed; great crop damage over entire section.	Do.
San Jon, N. Mex. (10 miles southeast of).	8					Small tornado	A few farm buildings wrecked	Do.
Wayne, Okla., and vicinity	8		2 mi.		75,000	Wind	Extensive damage to crops and other property	Do.
Westminster, Md	8				20,000	Electrical	2 barns and contents destroyed	Do.
Spur, Tex	9	10 p. m	2 mi.		50,000	Hail	Crops damaged	Do.
Lake Michigan, (near Grand Haven, Mich.).	10			25		Wind	Steamer Andaste foundered, losing entire crew	Do.
Olton, Tex	11	8–9 p. m	880		10,000	Hail	Crops considerably injured	Do.
Dillon, S. C	14	2 p. m	80		1,500	Small tornado	A warehouse damaged; 3 persons injured	Do.
Arizona (south-central and southeastern).	19–24				50,000	Wind, rain, and floods.	Much damage to roads, culverts, and bridges	Do.
Lee Ranch, N. Mex. (near)	25					Hail	75 per cent of crops ruined	Do.
Houghton, Mich	27	P. m				Thunderstorm, hail, and rain.	Windows broken; considerable damage to telephone and electric circuits.	Do.
Miami and Fort Lauderdale area, Fla.	28	P. m				5 tornadoes	Details not yet received	Do.
Florida (southern and western).	28–30			3	676,000	Tropical hurricane.	Heavy damage to fruit and truck, highways, telephone and telegraph lines, small boats and equipment, timber, buildings, power plants, and shops.	Do.
Grays Lake and Ava, Ill	29					Electrical	4 barns destroyed	Do.
Pottsville, Pa., and vicinity.	29–30				20,000	Hail and rain	Damage confined to flooding of cellars, washing of fields, etc.; several small bridges destroyed.	Do.

[1] Mi. signifies miles instead of yards.

RIVERS AND FLOODS

By R. E. SPENCER

No floods of importance occurred during September, except those in the South Atlantic and East Gulf States during the last three days and that in the Rio Grande in the vicinity of San Marcial, N. Mex., on the 23d. As the South Atlantic and East Gulf floods were in all cases merely forerunners of much more severe ones in early October, they will be discussed in the flood report for that month.

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The Rio Grande rise, resulting from heavy local rains about the 22d, exceeded by 0.5 foot the high-water record of last month at San Marcial, destroying the levee and completely flooding the town. Press accounts state that only three buildings remained standing after the flood. Incomplete reports of losses place the total at $92,000, divided as follows:

Tangible property	$60,000
Matured crops	10,000
Prospective crops	15,000
Livestock, etc	2,000
Suspension of business	5,000

[All dates in September unless otherwise specified]

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC DRAINAGE	*Feet*			*Feet*	
Santee: Rimini, S. C.	12	29	(1)		
Congaree: Columbia, S. C.	15	28	29	19.1	28
Broad: Blairs, S. C.	15	27	29	25.0	28
Saluda:					
Pelzer, S. C.	7	26	29	11.2	27
Chappells, S. C.	14	26	(1)	30.2	28
Savannah:					
Calhoun Falls, S. C.	6	27	27	8.7	27
Augusta, Ga.	32	26	29	46.3	27
Broad: Carlton, Ga.	11	17	17	11.0	17
		26	28	19.2	27
Altamaha:					
Charlotte, Ga.	15	28	(1)		
Everett City, Ga.	10	29	(1)		
Oconee: Milledgeville, Ga.	22	27	28	25.2	27
Ocmulgee: Lumber City, Ga.	15	29	30	15.6	29
EAST GULF DRAINAGE					
Chattahoochee: Norcross, Ga.	16	27	28	19.5	27
Etowah: Canton, Ga.	11	26	26	14.0	26
MISSISSIPPI DRAINAGE					
French Broad: Asheville, N. C.	4	27	28	5.0	27
Big Pigeon: Newport, Tenn.	6	26	26	[2] 8.0	26
Elk: Fayetteville, Tenn.	14	14	14	14.7	14
Canadian: Logan, N. Mex.	4			6.0	23
WEST GULF DRAINAGE					
Nueces: Cotulla, Tex.	15	22	24	18.4	23
Rio Grande:					
Albuquerque, N. Mex.	4			4.5	23
San Marcial, N. Mex.	2			[3] 6.0	23
PACIFIC DRAINAGE					
Colorado: Parker, Ariz.	7	(4)		11.9	June 2.
				9.4	Sept. 27-28
Gila: Kelvin, Ariz.	5			8.0	24

[1] Continued at end of month.
[2] Approximately.
[3] Last reading taken; levee collapsed shortly afterwards.
[4] Continued from last month.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, SEPTEMBER, 1929

By J. B. KINCER

General summary.—During the first decade the agricultural situation was materially improved by fairly general rains, especially with respect to the condition of the soil for preparation of winter grain seeding in the principal producing States, and many late crops were benefited also, but in general the rains came too late to be of widespread, marked benefit. In the Atlantic area moisture was helpful in general, but some areas were still too dry, while there was again too much rain in parts of the Southeast; the Gulf area, including the southern half of Texas, continued dry, on the whole. Droughty conditions were effectively relieved in most sections between the Mississippi River and the Rocky Mountains, but crops were mostly too far advanced to be helped. Severe drought continued over the far Northwest.

During the second decade there was more or less severe frost over a rather wide area, extending from Pennsylvania, the northern part of the Ohio Valley States, and much of Iowa northward. Considerable damage resulted to late crops and tender vegetation in some sections, but harm was rather spotted. Showers were helpful to minor crops in parts of the Southeast, but in other sections they were not needed and were mostly unfavorable for cotton in the eastern belt. It was still too dry for plowing and seeding winter grains in a good many places, especially in parts of the Ohio Valley and more generally in the Northwest and northern Pacific States.

During the last decade there were damaging and heavy rains in the Southeast, attending a tropical storm that moved northeastward over that section. Rains were frequent and in many places heavy, resulting in the washing of fields, flooding of lowlands, and damage to outstanding crops. Rainfall was still needed in some areas, the sections needing moisture most being Michigan, the northern portions of Indiana and Illinois, and Missouri and eastern Kansas. The drought was also largely unrelieved in the grain areas of the Pacific Northwest. The warm, sunny weather in the interior and Southwest favored rapid maturity of late crops and only local frost damage was reported.

Small grains.—During the first decade cold weather, with considerable snow in elevated northwestern sections, was unfavorable for late harvest and threshing, while plowing was still retarded in much of the Lake region and in the far Northwest because of dry soil. Soil moisture was improved, however, in most of the main winter-wheat States. During the second decade the soil was still too dry and hard for plowing in the northern parts of Indiana and Illinois, much of Missouri, and south-central and southeastern Kansas, while this work was hampered in Wisconsin and Minnesota. Satisfactory advance was made in the Great Plains region, except as noted above, but in much of the Northwest it was too dry for extensive operations. During the last decade there was some improvement in conditions for plowing and seeding winter wheat, but parts of the Southwest continued dry. Good progress in seeding was made in the eastern Ohio Valley, but parts of Indiana and Illinois continued dry. In Kansas seeding was nearly done in the western two-thirds, but this work was delayed in the east by dry soil.

Corn.—The corn crop was too far advanced during the first decade to benefit materially from the rains, although some of the late crop was helped. In Iowa early corn was too mature and the late too badly fired for material benefit, while in eastern Kansas most corn was mature and it was largely beyond frost damage in the northern Great Plains. During the second decade corn matured slowly, due to cool weather, from the Mississippi Valley eastward; in the western belt the crop was largely matured. Frosts were rather general in some northern Ohio Valley sections, with more or less damage to the late crop, while in Iowa the frost killed the leaves of corn, but penetrated husks only in local areas. During the last decade corn was reported practically all beyond frost danger in the western portion of the belt. In Iowa conditions were only fair for drying, but advance toward maturity was very good. At the close of the month much was still green in central and southern Illinois and 10 to 20 days were still required in Missouri.

Cotton.—During the first decade the severe drought that had prevailed in the western Cotton Belt was effectively relieved in Oklahoma, the northern half of Texas, and western Arkansas, but the rains came too late to greatly benefit the crop. Progress was very good in parts of Texas, but was mostly poor, with continued complaints of shedding and premature opening of small bolls. Progress ranged from fair to good in Oklahoma, with shedding and premature opening checked; east of the Mississippi River there was further deterioration because of dry weather in interior sections, while there was too much rain in other parts.

During the second decade conditions were favorable in the western belt and unfavorable in the east. In the western belt, where the period was sunny and practically

rainless, conditions were practically ideal for picking and ginning; in Texas the crop was largely made. The weather interfered with opening of bolls and delayed picking and ginning in the eastern belt; some damage to staple was reported where rains were heaviest.

Excellent conditions for picking and ginning prevailed during the last decade in the western belt and this work made rapid progress. In Oklahoma picking made satisfactory advance, although much of the crop was irregular with short and low-grade staple. In Texas, the crop was practically made, with poor prospects for a top crop. In the eastern belt heavy to excessive rains and floods were very unfavorable, especially in the Carolinas, Georgia, and parts of Alabama, with picking practically at a standstill.

Miscellaneous crops.—Pastures showed improvement in some sections, but in others they are short and poor. Livestock held up well. Potato digging was well advanced at the close of the month, and, except for some more or less local harm from frost, truck did well. Sugar-beet digging progressed and sugar cane was generally favored. Nearly all tobacco was cut in Kentucky at the close of the month. Much fruit was blown from the trees in Florida by the tropical storm; deciduous fruits were doing well in general, and the weather generally favored fruit drying in the Pacific Coast States.

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

The outstanding meteorological features of the month for the North Atlantic Ocean were the very severe tropical hurricane during the last decade, that will be described in the October issue, and the secondary disturbance along the coasts of the Southern Atlantic States that occurred during the same period.

Charts VIII to XV cover the period from the 23d to 30th, inclusive. Charts will also be prepared for the first few days in October, to appear in the next issue of the REVIEW, showing the track of the tropical disturbance as it moved northward along the American coast. Reports from a number of vessels are given in the table, but none of them apparently encountered the full strength of the storm, which at times reached hurricane force, as they were able to take advantage of the storm warnings and thus escape its maximum intensity.

Disturbances of extratropical origin were somewhat below the normal, as over the steamer lanes gales were not reported on more than four days in any 5° square, the maximum occurring between the forty-fifth and fiftieth parallels and thirty-fifth and forty-fifth meridians.

Fog was reported on from 12 to 14 days over the Grand Banks; on from 8 to 13 days along the American coast, north of the thirty-fifth parallel, and on from 3 to 6 days over the middle and eastern sections of the northern steamer lanes.

On the 1st and 2d a moderate disturbance was over the eastern section of the steamer lanes, with northeasterly gales between the forty-fifth and fiftieth parallels and twentieth and thirtieth meridians.

A well-developed LOW that was central on the 4th near 50° N., 38° W., remained nearly stationary during the next three days, when moderate to strong gales prevailed over an area extending on the 5th from the twenty-fifth to forty-fifth meridians.

From the 7th to 11th comparatively high pressure and slight gradients, accompanied by moderate weather, was the rule over the ocean as a whole, although a few vessels in different locations encountered moderate gales.

On the 12th a LOW central near 52° N., 32° W., was responsible for winds of force 7 to 9 that occurred on that day as well as on the 13th over the region between the thirtieth and forty-fifth meridians.

From the 14th to 18th there ensued another period of moderate weather, except that on the 17th westerly to southerly gales were reported off the north coast of Scotland.

A moderate depression that was off the coast of eastern Florida on the 18th developed into a severe disturbance as it moved northward, and from the 20th to 23d moderate to strong northeast gales swept the coast between Hatteras and New York.

On the 21st a well-developed LOW was over the Shetland Islands, and on the 22d a moderate depression was central near 50° N., 40° W.

As stated before, Charts VIII to XV cover the period from the 23d to 30th, inclusive, and, besides giving an idea of the movement of the tropical disturbance, also show the conditions over the eastern section of the steamer lanes, where heavy weather occurred on the 23d and again on the last three days of the month.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian). North Atlantic Ocean, September, 1929*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Belle Isle, Newfoundland	29.93	[1] +0.03	30.34	27th	29.34	11th.
Halifax, Nova Scotia	30.12	[2] +0.07	30.62	22d	29.74	11th.
Nantucket	30.11	[2] +0.03	30.50	22d	29.90	14th.
Hatteras	30.07	[2] −0.01	30.24	1st [3]	29.92	18th.
Key West	29.89	[2] −0.07	30.00	4th	29.40	28th.
New Orleans	29.96	[2] −0.04	30.08	1st	29.72	30th.
Cape Gracias, Nicaragua	29.84	[1] −0.07	29.90	4th	29.78	20th.
Turks Island	30.00	[2] +0.02	30.12	3d	29.94	18th. [3]
Bermuda	30.13	[2] +0.05	30.28	13th	29.90	25th.
Horta, Azores	30.18	[1] +0.02	30.44	20th	29.86	1st.
Lerwick, Shetland Islands	29.86	[1] +0.02	30.28	25th	29.12	21st.
Valencia, Ireland	30.13	[1] +0.14	30.36	7th [3]	29.90	3d.
London	30.11	[1] +0.11	30.50	25th	29.71	20th.

[1] From normals shown on Hydrographic Office Pilot Chart, based on observations at Greenwich mean noon, or 7 a. m. seventy-fifth meridian time.
[2] From normals based on 8 a. m. observations.
[3] And on other date.

Results for Julianehaab, Greenland, are not given, as seven days observations were missing from that station.

OCEAN GALES AND STORMS, SEPTEMBER, 1929

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	′				*Inches*					
Florida, Dan. S. S.	Antwerp	Charleston	47 08 N.	45 40 W.	Sept. 3	5 p., 3	Sept. 4	29.02	SSE.	NW.	WNW.	WSW, 9	WNW-NW.
Ala, Am. S. S.	Rotterdam	New York	50 10 N.	33 00 W.	3	1 a., 4	6	29.07	W.	WSW., 9	NNW.	WSW, 9	
Quaker City, Am. S. S.	Portland, Me	London	50 03 N.	37 50 W.	4	6 a., 4	5	29.04	SSW.	SSW., 7	SW.	SW., 9	Steady.
Malaren, Swed. M. S.	Gothenburg	Boston	53 32 N.	38 58 W.	5	8 a., 5	6		SE.	SE., 1	NNW.	E., 9	SE.-S.-W.-N.
Sacandaga, Am. S. S.	Antwerp	New York	51 00 N.	24 53 W.	10	11 p., 10	13	29.65	S.	SW., 6	WNW.	NW., 8	SW.-NW.
Cameronia, Br. S. S.	New York	Glasgow	49 33 N.	44 49 W.	11	4 a., 12	13	29.51	S.	WSW., 7	NW.	NW., 9	SW.-W.
Orla, Nor. S. S.	Newcastle	Portland, Me.	58 30 N.	12 40 W.	16	6 a., 17	17	29.67	S.	SW., 9	W.	SW., 9	SSW.-WSW.
Calamares, Am. S. S.	Canal Zone	New York	30 33 N.	79 35 W.	19	7 a., 20	23	29.94	NE.	NNE., 5	NE.	NE., 10	Steady.
Monterey, Am. S. S.	Habana	Progresso	28 32 N.	79 40 W.	20	Noon, 20	23	29.77	NW.	NE., 7	NE.	—, 10	NW.-N.-NE.
Wildwood, Am. S. S.	Hamburg	Savannah	53 10 N.	3 50 E.	20	2 a., 20	20	29.45	WSW.	—, 9	NW.	—, 9	
Oriskany, Br. S. S.	Philadelphia	Honduras	34 10 N.	74 31 W.	21	10 p., 21	21	29.91	NE.	NE., 9	SE.	—, 9	E.-SE.
Hellig Olav, Dan. S. S.	Oslo	Halifax	59 35 N.	5 21 W.	21	8 a., 21	21	29.17	S.	W., 6	WNW.	NW., 9	S.-W.-NW.
Essequibo, Br. S. S.	Callao, Peru	New York	26 02 N.	79 50 W.	21	4 a., 21	24	29.91	NNE.	NNE., —	ENE.	NE., 10	Steady.
Bellflower, Am. S. S.	Cork	do	50 37 N.	36 03 W.	22	7 a., 22	22	29.40	SSW.	SSW., 7	N.	N., 10	
West Durfee, Am. S. S.	London	Galveston	27 07 N.	72 50 W.	23	Mdt., 23	25	29.81	N.	N., 7	NNE.	NNE., 8	N.-NW.-NNE.
Hellig Olav, Dan. S. S.	Oslo	Halifax	57 40 N.	22 44 W.	22	7 a., 23	24	28.90	SSW.	WNW., 9	W.	WNW., 9	S.-WNW.
Cameronia, Br. S. S.	Glasgow	New York	55 10 N.	20 35 W.	21	8 a., 23	24	29.43	WNW.	SW., 10	WSW.	SW., 10	Steady.
Narcissus, Am. S. S.	Liverpool	Galveston	28 40 N.	71 20 W.	24	Mdt., 24	29	29.88	ESE.	ESE., 5	S.	ESE., 9	Do.
Calgarolite, Br. M. S.	Cartagena	Montreal	34 25 N.	68 05 W.	25	10 p., 25	26	29.60	N.	E., 9	SE.	ENE., 9	ENE.-ESE.
Tynefield, Br. M. S.	Hull	Baton Rouge	25 48 N.	77 30 W.	24	2 p., 26	28	29.66	SSE.	SE., 9	NE.	—, 10	ENE.-SE.
Wm. G. Warden, Am. S. S.	Montreal	Corpus Christi.	38 45 N.	67 35 W.	27	10 a., 27	27	29.84	S.	SSW., 10	W.	SSW., 10	S.-W.
Lempira, Hond. S. S.	Porto Cortez	New York	25 30 N.	79 55 W.	27	3 a., 28	28	29.45	NE.	ENE., 9	ENE.	—, 9	Steady.
Cameronia, Br. S. S.	Glasgow	do	42 15 N.	63 12 W.	28	9 a., 28	29	29.65	ENE.	NE., 8	NNE.	—, 8	NE.-N.
Oscar II, Dan. S. S.	Oslo	Halifax	59 35 N.	7 00 W.	27	1 p., 28	29	29.06	SSE.	SW., 11	WSW.	SW., 11	SSW.-WSW.
NORTH PACIFIC OCEAN													
Olympia, Am. S. S.	Shanghai	San Francisco	45 22 N.	153 00 W.	8	6 p., 8	8	29.38	SE.	SE., 8	SE.	SE., 8	Steady.
Texas, Am. S. S.	Hong Kong	do	40 25 N.	150 30 E.	9	Noon, 9	10	29.41	ESE.	E., 7	ESE.	NE., 9	E.-NE.
Chief Capilano, Br. S. S.	Everett	Shanghai	51 20 N.	170 45 W.	9	4 a., 9	10	29.02	NNE.	N., 8	NNW.	NNW., 9	N.-NNW.
Erviken, Nor. S. S.	Kobe	Manila	31 29 N.	132 53 E.	9	4 p., 9	10	29.47	E.	ENE., 7	NNW.	N., 9	E.-NNE.-N.
Hakonesan Maru, Jap. M. S.	Olympia	Yokohama	50 42 N.	169 47 W.	7	4 a., 9	12	29.10	SE.	N., 6	NW.	NNW., 8	NNE.-NNW.
Pres. Polk, Am. S. S.	San Francisco	Kobe	33 34 N.	144 35 E.	10	8 p., 10	11	29.52	SSW.	SSW., 7	NW.	SW., 9	SSW.-WNW.
Tokiwa Maru, Jap. S. S.	Yokohama	Victoria	43 05 N.	157 52 E.	10	6 p., 11	12	29.07	ENE.	ENE., 9	N.	—, 10	ESE.-E.-NE.
Yankee Arrow, Am. S. S.	do	San Pedro	44 47 N.	172 36 E.	11	1 a., 12	12	28.63	SE.	NE., 11	NW.	NE., 12	S.-E.-NE.
Calcutta Maru, Jap. S. S.	do	San Francisco	41 40 N.	167 12 E.	11	Noon, —	13		E.	WSW., —	NW.	W., 11	WSW.-WNW.
Siberia Maru, Jap. S. S.	Honolulu	Yokohama	34 47 N.	152 34 E.	11	2 p., 11	11	29.68	SW.	W., 9	WNW.	SW., 9	SW.-W.
Do	do	do	34 50 N.	141 22 E.	12	Mdt., 12	13	29.56	E.	S., 7	N.	N., 8	S.-W.-N.
Erie Maru, Jap. S. S.	Grays Harbor	Osaka	41 46 N.	153 28 E.	10	2 p., 11	11	29.35	E.	N., 9	NNW.	N., 9	Steady.
Do	do	do	39 07 N.	143 30 E.	13	4 p., 14	14	29.41	E.	NNE., 6	WNW.	E., 10	
Emp. of Asia, Can. S. S.	Yokohama	Vancouver	36 36 N.	144 03 E.	12	4 p., 13	13	29.18	NE.	E., 9	S.	E., 9	E.-SE.-S.
Nevada, Am. S. S.	Hakodate	San Francisco	47 35 N.	165 08 W.	12	Mdt., 12	14	29.14	SSE.	SSE., 9	WSW.	SSE., 9	SSE.-SSW.
Hakubasan Maru, Jap. M. S.	Yokohama	Seattle	46 31 N.	166 35 E.	12	Noon, 12	14	29.22	E.	ENE., —	WNW.	E., 9	
Pres. Grant, Am. S. S.	Victoria	Yokohama	51 31 N.	174 46 W.	11	12 p., 12	15	28.82	S.	NNE., 6	W.	NW., 8	E.-NE.-NNE.
Broad Arrow, Am. S. S.	Nagasaki	San Pedro	33 35 N.	137 15 E.	20	10 p., 21	22	29.59	NE.	NE., 9	NE.	NE., 10	Steady.
Hamburg Maru, Jap. S. S.	Yokohama	San Francisco	44 21 N.	162 17 E.	20	8 p., 20	22	29.72	W.	W., 7	NNW.	NW., 8	W.-NNW.
Steel Trader, Am. S. S.	Shanghai	Port Townsend.	50 10 N.	163 00 W.	23	Mdt., 23	24	28.91	SE.	SE., 10	SW.	SE., 10	SE.-SW.
Deebank, Br. S. S.	Manila	Hong Kong	34 20 N.	124 02 E.	25	6 p., 25	26	29.34	ESE.	ENE., —	NNW.	ENE., 8	ENE.-N.
Akibasan Maru, Jap. S. S.	Yokohama	San Francisco	47 49 N.	159 39 W.	27	Noon, 27	27	29.45	SSE.	SSE., 9	SW.	SSE., 9	Steady.
Wisconsin, Am. S. S.	Otaru	do	47 49 N.	172 36 W.	29	10 a., 30	Oct. 2	29.55	WNW.	S., 7	W.	W., 9	
MEXICAN WEST COAST GALE REPORTS													
Havana Maru, Jap. S. S.	Los Angeles	Balboa	15 03 N.	97 23 W.	10	4 p., 11	Sept. 11	29.66	E.	NE., 8	NE.	NE., 8	Steady.
Iowan, Am. S. S.	San Francisco	New York	17 00 N.	100 40 W.	11	—, 12	14	29.65	ESE.	E., 10	SW.	E, 12	
Atlantic, Am. S. S.	Everett	Balboa	17 01 N.	101 24 W.	12	4 a., 13	13	29.68	N.	ENE., 10	E.	ENE., 10	NE.-E.
Texas, Fr. S. S.	San Pedro	do	18 11 N.	104 32 W.	13	2 p., 13	14	29.39	E.	E., 10	ESE.	E., 12	Steady.
Munaires, Am. S. S.	Vancouver	Colon	17 15 N.	102 05 W.	13	4 a., 13	13	29.61	NE.	ENE., 10	E.	SE., 11	
Australien, Dan. M. S.	San Francisco	Balboa	18 45 N.	104 36 W.	13	4 a., 14	14	29.70	ESE.	ESE., 9	SE.	SE., 10	Steady.
Solana, Am. S. S.	do	do	20 23 N.	107 12 W.	14	4 p., 14	15	29.57	ESE.	ESE., 8	NE.	ESE., 8	Steady.
Steel Age., Am. S. S.	New Orleans	San Pedro	20 30 N.	106 29 W.	15	4 a., 16	16	29.59	SSE.	SSW., 9	SSW.	S., 9	S.-SSW.
Lancaster, Am. S. S.	San Francisco	Balboa	21 20 N.	108 20 W.	15	4 p., 15	16	29.50	ESE.	SE., 7	SSW.	SSW., 8	SE.-S.
Willpolo, Am. S. S.	Balboa	San Diego	22 51 N.	109 53 W.	15	8 a., 16	16	28.28	SE.	NNW., 12	WSW.	NNW., 12	
Nora, Am. S. S.	San Pedro	Iquique	28 41 N.	112 41 W.	16	1 p., 16	16	29.60	NW.	NW., 7	SSW.	W., 8	2 pts.
Do	do	do	18 20 N.	104 42 W.	19	6 a., 19	19	29.77	E.	E., 9	SW.	SW., 10	12 pts.
Corinto, Am. S. S.	San Francisco	Panama	13 48 N.	90 59 W.	24	3 a., 24	24	29.88	SE.	SE., 8	E.	SE., 8	SE.-E.
Oilfield, Br. S. S.	San Pedro	Havre	15 00 N.	96 30 W.	24	—, 24	24	29.56	NE.	NE., —	SE.	E., 9	E.-SE.
SOUTH PACIFIC OCEAN													
Canad. Scottish, Can. S. S.	Brisbane	Panama	32 10 S.	120 30 W.	2	4 p., 3	5	29.21	SE.	SW., 7	NW.	S., 10	S.-SW.-SE.
Pilar de Larrinaga, Br. S. S.	Durban	Melbourne	45 04 S.	115 16 E.	3	5 a., 4	5	29.36	NW.	NW., —	W.	NW., 9	Steady.
Lantaro, Br. M. S.	Montevideo	Magellan	50 23 S.	76 45 W.	8	Noon, 9	10	29.26	NW.	NW., 10	W.	NW., 10	NW.-W.
West Notus, Am. S. S.	Los Angeles	Montevideo	36 40 S.	88 39 W.	12	10 p., 12	14	29.81	ENE.	ENE., 7	E.	E., 9	ENE.-E.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

A remarkable change took place in the atmospheric pressure of the central Aleutian region in September as compared with that of August. In the earlier month the Aleutian cyclone, on the average, had become practically nonexistent, except for a shallow depression covering the upper part of the Gulf of Alaska. The Pacific-California HIGH at that time extended northward over the central part of the ocean to Dutch Harbor, where the average was 30.04 inches. In September the HIGH covered the central and northeastern parts of the ocean, but the LOW had developed extraordinarily to less than average winter depth, the monthly averages at Dutch Harbor and St. Paul dropping each to 29.51 inches, with the minus departure from the August reading at Dutch Harbor amounting to 0.53 inch. As there was little pressure change between the months at Kodiak, it is seen that the centers of cyclonic activity in September operated principally to the westward of the Gulf of Alaska. The greatest intensifications of the Aleutian LOW occurred on the 13th and 24th.

Barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean, are given in the following table:

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean and adjacent waters, September, 1929*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow [1] [2]	30.03		30.48	9th	29.74	17th.
Dutch Harbor [1] [2]	29.51	−0.25	30.06	18th	28.62	13th.
St. Paul [1] [3]	29.51	−0.19	30.22	7th	28.96	24th.[7]
Kodiak [1] [3]	29.85	+0.15	30.20	7th	29.48	14th.
Midway Island [1] [4]	30.05	−0.02	30.28	26th	29.80	12th.
Honolulu [5]	29.98	−0.02	30.05	29th	29.87	20th.
Juneau [5]	30.12	+0.20	30.32	5th	29.62	13th.
Tatoosh Island [5] [6]	30.03	+0.02	30.22	28th	29.75	16th.
San Francisco [5] [6]	29.88	−0.10	30.05	28th	29.74	15th.
San Diego [5] [6]	29.84	−0.04	29.99	28th	29.59	16th.

[1] P. m. observations only.
[2] For 29 days.
[3] For 28 days.
[4] For 27 days.
[5] A. m. and p. m. observations.
[6] Corrected to 24-hour mean.
[7] Also on 25th.

No gales were reported by seamen as occurring along the American coast between the thirtieth and sixtieth parallels. But with the abrupt change barometrically from quiet summer to active autumn conditions in central higher latitudes of the Pacific, there occurred a considerable increase in storminess both as to numbers and force of the gales encountered by steamships traversing the more northerly routes between meridians 155° W. and 180°. In some localities here gales were observed on from five to seven days of the month, the forces ranging from 8 to 10. To the westward gales decreased in number almost to the Japanese coast, but on the 12th attained great violence between latitudes 40° and 50° N., longitudes 165° and 175° E., where whole gales to hurricane velocities were reported. Most heavily involved at this time was the American steamship *Yankee Arrow*, A. Andersen, master; A. H. Jones, second officer and observer. This vessel "hove to, with wind and sea on port bow, from 1 a. m. to 7 a. m." of the 12th, battling a northeast hurricane, lowest pressure 28.63 inches, in 44° 47′ N., 172° 36′ E.

Of the gales that swept the near coast waters, south and east, of Japan, practically all resulted from the passage of typhoons or milder tropical disturbances. High winds of this character, forces 8 to 10, were reported as of the 9th to 14th, inclusive, and on the 21st and 22d. Probably gales of greater force, though as yet unreported, blew off the south coast on the 29th and 30th, due to the presence there of the typhoon mentioned by the Rev. José Coronas, of the Philippine Weather Bureau, in his subjoined article. The Philippines typhoon of the 17th and 18th was reported by the Dutch steamship *Modjokerto*, which encountered a southwest gale of force 8, lowest barometer 29.68, a short distance outside of Manila, on the 18th.

Mexican west coast waters were visited by gales, some of hurricane intensity, on at least 10 days of the month. These resolved themselves into a principal tropical cyclone of the 10th to 18th, a perhaps local disturbance of the 19th, and a pronounced depression of the 23d and 24th. The major storm, being of considerable importance, is described in a separate article. The storm of the 19th may have been identified with the general disturbed conditions prevailing for several days off the Mexican coast, or it may have been a cyclone with individual characteristics. So far as reports show, however, it was experienced only by the American tanker *Nora*, which encountered strong to whole east to southwest gales between Acapulco and Manzanillo. The fresh to strong gales of the 23d and 24th are to be identified as belonging to a cyclonic wind system occurring south and southeast of the Gulf of Tehuantepec. The lowest pressure observed was 29.56 inches read on board the British steamship *Oilfield* on the 24th, in 15° N., 96° 30′ W. This vessel, southbound, passed the center of the disturbance, with east changing to southeast wind, between 10 a. m. and noon, barometer thereafter rapidly rising. It is not yet known if the cyclone filled up or passed out to sea.

The prevailing wind direction at Honolulu was east, and the maximum velocity was at the rate of 22 miles an hour from the east on the 28th. The month here was one of the warmest Septembers on record.

Fog declined rapidly in occurrence over that part of the northern steamship routes west of the one hundred and eightieth meridian, the percentage falling from 50 in August to about 10 or 15 in September. Fog was slightly more frequent along the part of the upper routes lying south of the Gulf of Alaska, but was most frequent along the American coast from Alaska to the northern part of Lower California. Off most of the coast of the United States proper at least 50 per cent of the days had fog. The phenomenon occurred locally on the 6th off the Costa Rican coast and on the 9th in the lower part of the Gulf of Tehuantepec. Off the Washington and Oregon coasts visibility was often poor or obscured, due to smoke or combined smoke and fog. The American steamship *Admiral Peoples* on the 7th reported low visibility from Yaquina Head to the Columbia River, due to smoke, and the American steamship *Emma Alexander* further reported:

> Left Victoria at 9.30 a. m., 15th. Encountered smoke in Straits, becoming dense off coasts of Washington and Oregon; 17th, heavy smoke to dense fog, all due to extensive forest fires.

THE MEXICAN WEST COAST HURRICANE OF SEPTEMBER 10–18, 1929

By WILLIS E. HURD

This severe storm originated, so far as reports indicate, near or over the southwestern waters of the Gulf of Tehuantepec as early, at least, as the 10th, when the Japanese steamship *Havana Maru*, southbound, experienced a moderate north-northeasterly gale and falling

barometer. At 4 a. m. on the 11th the same vessel, near 15° N., 97° W., reported a fresh northeast gale, barometer down to 29.66. On the same day the American steamship *Iowan* met with gales from ESE., force 8–10, near 21° N., 107° W., with slightly depressed barometer. On the 12th the *Iowan* had gales of similar force from the east near 17° N., 101° W.

Radio reports of the 12th received by the French steamship *Texas* from several vessels, and furnished by her to the Weather Bureau, show that fresh gales to hurricane squalls from east, southeast, and southwest directions occurred between 15° and 17° N., 99° and 103° W. On the 13th and 14th the weather was stormy along much of the coast from slightly above Salina Cruz to the mouth of the Gulf of California, with heavy easterly to southeasterly gales reported from Acapulco, Manzanillo, and Mazatlan. On the 13th the cyclone had become undoubtedly severe, with the center localized at near 18° N., 104° W., where the *Texas* encountered a full easterly hurricane with very heavy rain early in the afternoon, lowest barometer 29.39. Later in the day, as she proceeded southward, her pressure rose, with diminishing southeast gales.

On this date the American steamship *Munaires*, bound toward the canal, ran into gales from northeast early in the morning, barometer 29.69, in 17° 20′ N., 102° 10′ W. Apparently she was hove to for the better part of the day, while the wind changed to east, then southeast, increasing to force 11 at 10 a. m., and decreasing to force 7 at 8 p. m. As the gale rose, however, so did the pressure, according to the report furnished by third officer and observer, O. R. Smith, the barometer reading 29.81 at the height of the storm. "There were no unusual weather conditions," said Mr. Smith, "to give warning of the approach of this storm excepting the heavy seas which were encountered some eight hours before the storm."

During the 14th and 15th no gales were reported higher than force 10, but it was apparent that the central area of the cyclone was moving up the coast and at no great distance from it.

On the 16th, although observations failed to come through from neighboring land stations, the full intensity of the storm at sea became manifest. The American steamship *Willpolo*, Balboa to San Diego, had a barometer of 28.94, wind ESE., 9, at 6 a. m., in 22° 51′ N., 109° 53′ W. At 6.30 the wind had increased to force 10, barometer 28.74; at 6.40 the wind had become an east hurricane, and at 7 the barometer read 28.32 (corrected). At about 7.30 the hurricane wind changed to north, then went into north-northwest at 8.10, barometer lowest at 28.28. At noon the wind was west, force 10, weather moderating. The American tanker *Nora* reported fresh gales during the afternoon well up in the Gulf of California.

The cyclone swept rapidly northward on the 16th with great loss of intensity, and entered southern California, lowest barometer at San Diego, 29.59. At morning observation of the 17th at this station the temperature attained the extraordinary height of 93°, the record maximum for that hour (4.45 a. m.), with wind off the desert. It was followed by sprinkles during a part of the forenoon, and at 4.10 p. m. by a maximum wind velocity of 28 miles from the southeast, which is the record velocity at San Diego for September. On the 18th all that remained of this Mexican hurricane was a shallow elongated low lying north and south to the eastward of San Francisco.

This is the first cyclone of the Mexican west coast during the 20-year period 1910–1929, known by the writer to have pursued a course thus northward into California. The only other storm of the period, the track of which has actually been traced into the extreme southwestern part of the United States, was that of September, 1921, which passed up the west coast of Mexico, caused damaging rains in southwestern Arizona, then went northeastward as a fully formed cyclone, and before dying out in October nearly crossed the Atlantic Ocean.

FURTHER NOTE ON THE PHILIPPINE TYPHOON OF APRIL 25–26, 1929

By WILLIS E. HURD

In the April issue of the REVIEW mention was made of a press report of a typhoon experienced April 25–26, 1929, by the American steamship *Edgefield*, Capt. W. H. Walker, Sagay, P. I., to San Pedro. The Weather Bureau now has Captain Walker's own report of the storm, which he characterized as being of small area but of great intensity and the worst of five typhoons of his experience. He noted that "we were approximately 300 miles from the place where the *Elkton* was lost with all hands in 1927."

At noon of the 24th the *Edgefield* was in latitude 14° 46′ N., longitude 126° 50′ E., wind NE., 5, barometer 29.62 (uncorrected), rough head sea. Twenty-four hours later she was in 16° 16′ N., 128° 41′ E., wind ENE., 6, barometer 29.57. At 3 a. m. of the 26th she was in the outer edge of the typhoon center, wind west, 12, barometer 28.10, pressure having fallen exactly 1 inch in two hours. Quoting now from the captain's report:

> 25th. Wind increasing rapidly as midnight approached and barometer falling, with tremendous confused sea.
>
> 26th. Center of typhoon passed over vessel about 3 a. m., with wind practically calm and atmosphere very oppressive. From 1.50 to 2.35 a. m., just before center, vessel refused to steer, owing to force of wind, and fuel oil was pumped overboard in effort to calm seas. After passage of center, weather and sea moderated rapidly.

TYPHOONS AND DEPRESSIONS—A DESTRUCTIVE TYPHOON OVER SOUTHERN AND CENTRAL LUZON ON SEPTEMBER 2 AND 3, 1929

By Rev. José CORONAS, S. J.

[Weather Bureau, Manila, P. I.]

This is the first destructive typhoon we have had over the Philippines since the *Euzkadi* typhoon of last November. The track followed by this typhoon during the first two days of September was very dangerous for Manila, where all possible precautions had been taken. But fortunately the typhoon, which had been moving west by north, inclined northwestward just in time to save our city from a real calamity.

Our weather map showed the first signs of this typhoon at 6 a. m. of September 1, when the center was situated about 350 miles to the east by south of Manila not far from 127° longitude E. and 14° latitude N. It moved rather slowly westward, with a little inclination to the north, and was severely felt on the 2d in the sub-Province of Catanduanes and the Provinces of Sorsogon, Albay, Camarines Sur, and Camarines Norte. At 6 a. m. of the 3d the center passed very near to the northern coast of Camarines Norte, headed for Polillo Island and Infanta, a municipality of Tayabas Province situated about 45 miles to the east of Manila. Our observer of Infanta reported a barometric minimum of 722 millimeters (28.43 inches, gravity correction not

applied) at 12.15 p. m. of the 3d, and we know from reliable sources that a good aneroid barometer of Polillo fell to 716 millimeters (28.19 inches) while the vortical calm was observed.

As stated above, the typhoon inclined to northwest when the center was practically over Infanta, but after only six hours it took again the former west by north direction, which was kept across the China Sea until the center reached Paracels; then it moved west-northwest, passing at 2 p. m. of the 6th near to the south of the Gulf of Tongking.

As it was to be expected, very intensive damage was done by hurricane winds and heavy floods that followed the typhoon in Infanta and Polillo, thousands of people having been left homeless and destitute, while a good number were either missing or found dead. In other parts of Luzon the losses caused by the winds were not so great as those caused by the floods, which are considered very extraordinary. The water supply of Manila was seriously affected by a break in the water mains as a result of these floods.

Up to the present our stations that reported the heaviest rains are those of Virac and Daet. The observer of Virac reported 488 millimeters (19.21 inches) for the 1st of September and 392 millimeters (15.43 inches) for the 2d: a total of 880 millimeters (34.64 inches) in 48 hours. At Daet the amount of rain collected on the 1st and 2d was 124.9 millimeters (4.92 inches) and 470.7 millimeters (18.53 inches), respectively; a total amount of 595.6 millimeters (23.45 inches) in 48 hours. We will never know the amount of rain falling at Infanta, as the rain gage was carried away by the winds and the floods.

The number of lives lost in this typhoon was over 200. The railroad steamer *Mayon* sunk off the coast of Luzon near Pasacao on September 2. The provinces most severely affected by this typhoon were Tayabas, Albay (including Catanduanes Island), Camarines Norte, Camarines Sur, Sorsogon, Rizal, Bulacan, Pampanga, Nueva Ecija, and Tarlac.

The approximate position of the center on the period September 1 to 6 was as follows:

September 1, 6 a. m., 127° 05′ longitude E, 14° 00′ latitude N.
September 2, 6 a. m., 124° 50′ longitude E, 14° 10′ latitude N.
September 3, 6 a. m., 122° 35′ longitude E, 14° 35′ latitude N.
September 3, 2 p. m., 121° 20′ longitude E, 15° 00′ latitude N.
September 4, 6 a. m., 118° 55′ longitude E, 16° 00′ latitude N.
September 5, 6 a. m., 113° 30′ longitude E, 16° 30′ latitude N.
September 6, 6 a. m., 108° 30′ longitude E, 17° 30′ latitude N.

Besides the destructive Luzon typhoon of September 2d to 3d, there were in the Far East during the month of September five or six other typhoons of less or no importance for the Philippines.

On September 17 a small typhoon center was noticed over the Camarines Provinces which caused an unprecedented flood in Camarines Sur. It was reported that even the highest ground on the town of Nabua was covered by water to a depth of nearly 3 feet. Other towns of Camarines Sur were reported also as completely submerged. In Naga, the capital of the Province, the lower parts of the town were covered to a depth of from 2 to 3 feet. The total daily rainfall reported from that place for the 17th was 227.8 millimeters (8.97 inches). The small typhoon moved northwestward and passed to the north of Manila in the morning of the 18th. Across the China Sea it moved almost westward until the afternoon of the 20th, when it moved again northwest not far from the coast of Indo-China. With the exception of the floods of Camarines Sur, not much damage was done by this typhoon.

On September 8 to 9 a well-developed typhoon was recurving northeastward about 300 miles southeast of the Loochoos. Its center was shown in our noon weather map of September 10 as passing southeast of Tokyo near the coast of Japan. The approximate positions of this typhoon at 6 a. m. of September 9 to 11 were as follows:

September 9, 6 a. m., 131° 30′ longitude E, 25° 00′ latitude N.
September 10, 6 a. m., 136° 35′ longitude E, 31° 35′ latitude N.
September 11, 6 a. m., 152° 00′ longitude E, 40° 50′ latitude N.

Another typhoon center moved northeastward about 300 miles north of Guam on September 6.

Two typhoon centers of a similar track moved first to north-northwest from the Pacific east of Balintang Channel and then recurved eastward in the neighborhood of the northern Loochoos. Both were shown in our weather maps of September 19 to 22, and September 27 to 30, respectively. The approximate positions of these two centers for each day were:

First typhoon:
September 19, 6 a. m., 127° 30′ longitude E, 20° 25′ latitude N.
September 20, 6 a. m., 126° 00′ longitude E, 25° 15′ latitude N.
September 21, 6 a. m., 128° 45′ longitude E, 29° 15′ latitude N.
September 22, 6 a. m., 136° 40′ longitude E, 30° 20′ latitude N.

Second typhoon:
September 27, 6 a. m., 129° 00′ longitude E, 20° 20′ latitude N.
September 28, 6 a. m., 127° 25′ longitude E, 23° 30′ latitude N.
September 29, 6 a. m., 129° 00′ longitude E, 28° 00′ latitude N.
September 30, 6 a. m., 136° 00′ longitude E, 28° 10′ latitude N.

Finally, our weather maps showed a small typhoon center which followed a very peculiar track from September 5 to 10. It moved almost north over the Pacific more than 400 miles east of Balintang Channel and Formosa, and then recurved gradually to northwest, west, southwest, and south-southwest in the neighborhood of Naha, Loochoo Islands. The approximate position of the center day by day from September 5 to 10 was as follows:

September 5, 6 a. m., 130° 05′ longitude E, 20° 05′ latitude N.
September 6, 6 a. m., 129° 15′ longitude E, 24° 35′ latitude N.
September 7, 6 a. m., 128° 00′ longitude E, 27° 00′ latitude N.
September 8, 6 a. m., 125° 05′ longitude E, 24° 50′ latitude N.
September 9, 6 a. m., 122° 00′ longitude E, 21° 55′ longitude N.
September 10, 6 a. m., 120° 00′ longitude E, 18° 45′ latitude N.

On the 9th and 10th the typhoon was filling up gradually while continuing moving south-southwest. It had disappeared already on the 11th.

CLIMATOLOGICAL TABLES[1]

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, September, 1929

Section	Temperature								Precipitation					
			Monthly extremes								Greatest monthly		Least monthly	
	Section average	Departure from the normal	Station	Highest	Date	Station	Lowest	Date	Section average	Departure from the normal	Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	74.7	−0.7	2 stations	98	[2]10	Riverton	43	19	5.83	+2.56	Dothan	13.86	Dadeville	2.93
Arizona	74.0	+0.3	Mohawk	114	1	Alpine	25	8	1.88	+0.64	Benson	6.18	Mohawk	0.08
Arkansas	73.4	−0.8	2 stations	102	[2]1	2 stations	41	19	2.46	−0.97	Waters	5.86	Pine Bluff	0.31
California	66.5	−0.8	Brawley	117	13	Portola	12	25	0.19	−0.35	Cuyamaca	3.21	114 stations	0.00
Colorado	55.5	−2.1	Sedgwick	100	2	2 stations	15	9	2.60	+1.20	Terminal Dam	6.38	Nast	0.33
Florida	79.2	−0.2	3 stations	97	[2]8	Mount Pleasant	49	21	10.98	+4.21	Fellsmere	25.15	New Smyrna	3.94
Georgia	74.3	−1.0	do	97	[2]6	Clayton	44	19	9.62	+6.15	Glennville	24.51	Montezuma	2.68
Idaho	54.2	−2.9	2 stations	99	[2]16	New Meadows	13	22	0.54	−0.44	Grace	2.67	3 stations	0.00
Illinois	66.1	−1.3	do	96	[2]2	Freeport	30	18	2.94	−0.68	Golconda	8.17	Danville	0.66
Indiana	66.1	−0.9	South Bend	99	2	Wheatfield	28	19	3.05	−0.07	Evansville	6.50	Veedersburg	1.08
Iowa	62.4	−1.9	Decorah	98	2	3 stations	25	18	3.74	+0.07	Perry	7.36	Dubuque	1.55
Kansas	67.2	−2.4	2 stations	105	1	Atwood	34	10	1.91	−0.88	Minneola	3.70	Independence	0.32
Kentucky	69.5	−0.9	Beaver Dam	97	5	Farmers	35	20	4.69	+1.86	Burnside	8.54	Hopkinsville	1.83
Louisiana	77.6	−0.3	Dodson	102	9	4 stations	51	[2]19	4.28	+0.32	New Orleans (No. 2)	17.10	Plain Dealing	0.60
Maryland-Delaware	68.3	+0.8	2 stations	100	3	2 stations	25	19	3.62	+0.36	Maryland Line, Md.	7.73	Newburg, Md	0.68
Michigan	60.2	+0.1	do	98	[2]2	Wolverine	19	19	1.76	−1.45	Ruse	6.01	Howard City	0.73
Minnesota	56.1	−2.2	Beardsley	103	2	2 stations	14	[2]17	3.80	+0.93	Willmar	8.51	Red Lake Falls	0.80
Mississippi	75.8	−0.4	2 stations	100	[2]1	Eupora	45	19	4.22	+1.28	Bay St. Louis	19.16	Vicksburg	0.34
Missouri	67.4	−1.6	3 stations	98	[2]2	Unionville	33	18	3.20	−0.64	Morehouse	7.32	Nevada	0.88
Montana	51.0	−3.9	Plevna	103	1	Conway's ranch	12	7	1.36	0.00	Adel	4.45	Missoula	0.10
Nebraska	60.0	−3.9	Sidney	110	[2]1	2 stations	28	[2]5	2.82	+0.69	Butte	8.06	Western	0.75
Nevada	61.0	−0.8	Las Vegas	107	[2]15	Rye Patch	14	28	0.34	−0.08	Kimberly	2.04	16 stations	0.00
New England	61.5	+1.9	Springfield, Mass	102	5	Chelsea, Vt	21	[2]20	2.47	−0.99	Nantucket, Mass	5.88	North Grosvenor Dale, Conn.	0.55
New Jersey	67.0	+1.5	Elizabeth	100	4	Layton	28	21	4.74	+1.11	Hightstown	8.24	Atlantic City	2.12
New Mexico	63.6	−0.3	Richland	101	5	Therma	13	17	2.10	+0.51	Selsor Ranch	7.02	Orogrande	0.10
New York	63.2	+2.1	Scarsdale	102	3	Indian Lake	19	[2]20	3.22	−0.23	Conklingville	7.73	Harkness	1.12
North Carolina	69.8	−0.3	2 stations	95	6	Banners Elk	30	[2]19	5.82	+2.07	Rock House	18.09	Neuse	1.61
North Dakota	52.7	−3.7	Maddock	105	1	Lisbon	12	17	1.65	+0.01	Hankinson	4.31	Mayville	0.21
Ohio	65.5	0.0	Washington Court-house.	99	3	Canfield	28	19	3.02	+0.01	Batavia	6.17	Lakeview	1.47
Oklahoma	72.4	−1.6	2 stations	106	[2]1	2 stations	38	10	3.93	+0.48	Antlers	9.16	Ralston	0.68
Oregon	57.7	−0.6	Oakridge	103	16	Harney Branch Experiment Station.	12	27	0.28	−1.12	Headworks	1.56	16 stations	0.00
Pennsylvania	65.7	+1.7	Lewisburg	101	3	2 stations	24	19	3.71	+0.23	Zelienople	8.72	Pittsburgh	1.05
South Carolina	72.6	−1.8	Trenton	97	6	Caesars Head	39	20	7.36	+3.18	Garnett	16.53	Florence (No. 1)	1.67
South Dakota	56.9	−4.0	Academy	110	2	3 stations	20	18	3.21	+1.52	Sioux Falls	8.28	Ottumwa	0.94
Tennessee	71.2	0.0	2 stations	98	[2]6	Crossville	35	19	4.79	+1.73	Sewanee	9.69	Memphis	1.62
Texas	77.4	+0.2	3 stations	106	[2]3	Dalhart	40	10	2.74	−0.14	Sherman	8.05	2 stations	0.00
Utah	59.4	−1.3	do	99	[2]1	Soldier Summit	23	28	2.23	+1.09	Huntsville	4.90	Fort Duchesne	0.10
Virginia	68.7	+0.5	Woodstock	98	[2]2	Burkes Garden	26	19	2.63	−0.79	Wallaceton	7.95	Burkes Garden	0.21
Washington	57.9	+0.1	Wahluke	100	[2]12	Newport (a)	19	30	0.45	−1.54	Index (Sunset Mine)	1.89	2 stations	T.
West Virginia	66.5	+0.8	Moorefield	102	3	2 stations	24	[2]19	2.95	−0.21	Sutton	6.25	Wardensville	0.57
Wisconsin	59.1	−0.6	High Falls	101	3	do	20	18	3.55	−0.06	Grantsburg	7.23	Plum Island	0.72
Wyoming	51.6	−3.6	Dull Center (near)	103	1	Dome Lake	14	8	2.08	+0.69	Sundance	3.93	Deaver	0.15
Alaska (August)	52.3	−0.8	Skagway	87	3	McKinley Park	24	29	3.21	+0.13	Ketchikan	21.07	White Mountain	0.21
Hawaii	75.9	+1.7	2 stations	95	[2]9	Volcano Observatory.	53	15	2.61	−3.51	Keauhou (No. 2)	18.84	4 stations	0.00
Porto Rico	78.7	−0.2	Canovanas	95	18	Lares	61	7	8.00	+0.01	Maricao	24.61	Quebradillas	4.07

[1] For description of tables and charts, see REVIEW, Januaay, 1929, p. 36.

[2] Other dates also.

TABLE 1.—*Climatological data for weather bureau stations, September, 1929*

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	°*F.*		°*F.*	°*F.*		°*F.*	° *F.*	° *F.*	° *F.*	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
New England							**62.4**	**+1.6**										**80**	**2.51**	**−0.6**										**5.7**		
Eastport	76	67	85	30.02	30.10	+0.07	56.8	+1.0	81	2	64	40	21	50	29	52	49	80	4.28	+1.5	14	5,392	s.	25	nw.	11	6	6	18	6.8	0.0	0.0
Greenville, Me	1,070	6	----	28.94	30.12	------	56.3	------	84	2	66	29	21	46	39	----	----	----	1.65	------	11	4,084	se.	27	------	2	8	6	16	----	0.0	0.0
Portland, Me	103	82	117	30.01	30.13	+.08	60.3	+0.7	96	3	69	38	20	52	35	55	52	78	2.09	−1.0	10	4,242	e.	21	nw.	11	13	5	12	5.3	0.0	0.0
Concord	289	70	79	29.80	30.11	+.05	60.2	+0.9	93	3	72	30	20	48	50	----	----	----	2.23	−1.2	9	2,580	ne.	17	nw.	3	10	7	13	6.0	0.0	0.0
Burlington	403	11	48	29.65	30.09	+.03	60.6	+0.3	91	3	71	29	21	50	37	----	----	----	1.42	−2.1	10	5,447	s.	30	s.	16	6	11	13	6.2	0.0	0.0
Northfield	876	12	60	29.18	30.13	+.07	58.2	+2.1	92	3	71	22	21	46	48	53	51	86	2.39	−0.7	9	3,740	s.	19	s.	10	6	9	15	6.8	0.0	0.0
Boston	125	106	165	29.97	30.11	+.04	65.2	+2.0	97	3	74	40	21	57	28	58	55	75	0.76	−2.4	11	4,514	sw.	26	nw.	11	7	12	11	6.2	0.0	0.0
Nantucket	12	14	90	30.10	30.09	+.02	64.8	+2.0	85	3	71	50	24	59	22	60	58	86	5.88	+3.4	11	10,146	ne.	36	ne.	27	11	10	9	5.3	0.0	0.0
Block Island	26	11	46	30.06	30.09	+.01	64.6	+1.2	87	3	70	46	19	59	20	61	58	84	3.57	+0.9	10	9,758	ne.	31	n.	27	8	12	10	5.8	0.0	0.0
Providence	160	215	251	29.94	30.11	+.04	64.6	+1.4	95	3	74	39	21	56	28	59	55	76	2.27	−0.9	11	5,971	n.	32	n.	11	14	6	10	4.8	0.0	0.0
Hartford	159	122	----	29.94	30.11	+.04	65.3	+3.6	95	4	76	38	21	55	40	----	----	----	1.39	−2.1	8	------	sw.	----	----	----	13	8	9	5.1	0.0	0.0
New Haven	106	74	153	30.00	30.11	+.04	66.1	+2.6	95	3	75	40	21	57	29	59	56	75	1.31	−2.2	10	5,026	n.	23	s.	10	16	6	8	4.4	0.0	0.0
Middle Atlantic States							**68.2**	**+1.4**										**77**	**3.95**	**+0.8**										**5.1**		
Albany	97	107	115	30.00	30.10	+.03	65.4	+2.3	97	4	76	36	21	55	35	57	54	74	3.45	+0.3	10	3,685	s.	23	sw.	10	15	10	5	4.0	0.0	0.0
Binghamton	871	10	84	29.18	30.11	+.04	64.8	+3.5	94	3	77	32	21	53	38	----	----	----	2.55	−0.5	10	2,987	ne.	19	sw.	10	12	10	8	4.8	0.0	0.0
New York	314	414	454	29.77	30.10	+.02	68.8	+2.0	94	3	76	44	19	61	26	61	57	72	4.05	+0.7	9	7,719	e.	37	nw.	11	5	13	12	6.1	0.0	0.0
Bellefonte	1,050	5	36	29.00	30.11	------	64.2	------	95	3	78	29	19	51	45	57	53	77	3.19	------	12	------	s.	----	----	----	9	11	10	5.3	0.0	0.0
Harrisburg	374	94	104	29.72	30.12	+.04	67.4	+1.6	96	3	77	41	21	58	32	60	55	71	5.10	+2.0	9	3,203	ne.	21	ne.	7	8	12	10	5.3	0.0	0.0
Philadelphia	114	123	367	29.99	30.12	+.04	70.3	+2.3	94	3	79	45	19	62	27	62	58	72	6.51	+3.4	9	7,644	sw.	44	sw.	8	11	8	11	5.1	0.0	0.0
Reading	325	81	98	29.76	30.11	------	68.0	------	96	3	78	41	19	58	31	60	56	72	4.31	+1.1	9	3,170	se.	22	w.	14	13	8	9	4.9	0.0	0.0
Scranton	805	111	119	29.26	30.12	+.05	65.6	+2.7	96	3	77	35	21	54	40	58	55	75	3.26	+0.1	8	3,475	sw.	22	sw.	13	9	13	8	5.3	0.0	0.0
Atlantic City	52	37	172	30.04	30.10	+.03	67.6	+0.8	86	1	73	44	19	62	21	64	61	83	2.12	−0.5	5	10,688	s.	40	ne.	22	9	12	9	5.2	0.0	0.0
Cape May	17	13	49	----	----	------	67.2	−1.8	85	1	74	44	20	60	23	64	62	84	2.19	------	8	------	ne.	----	----	----	13	8	9	----	0.0	0.0
Sandy Hook	22	10	55	30.07	30.09	------	68.1	------	93	3	75	49	19	61	25	62	59	79	4.89	+1.5	10	8,437	sw.	34	n.	18	12	7	11	5.3	0.0	0.0
Trenton	190	159	183	29.90	30.10	------	67.8	------	95	4	78	41	19	58	32	61	57	76	7.14	+3.7	10	5,768	sw.	32	sw.	7	9	8	13	5.6	0.0	0.0
Baltimore	123	100	215	29.97	30.10	+.02	70.4	+1.9	96	2	79	44	19	62	27	62	59	72	4.79	−0.6	9	5,574	ne.	30	nw.	14	12	12	6	4.8	0.0	0.0
Washington	112	62	85	29.98	30.10	+.02	70.2	+2.1	97	2	81	44	20	60	36	62	58	75	4.32	+1.1	8	2,989	s.	25	nw.	14	10	12	8	4.8	0.0	0.0
Cape Henry	18	8	54	30.06	30.08	------	72.2	------	90	8	78	56	19	66	26	67	65	82	5.52	+2.7	9	8,747	ne.	43	ne.	22	9	7	14	5.7	0.0	0.0
Lynchburg	681	153	188	29.37	30.11	+.03	70.0	+1.0	93	6	80	39	20	60	37	62	59	76	2.20	−1.1	6	3,999	ne.	24	ne.	30	15	7	8	4.6	0.0	0.0
Norfolk	91	170	205	30.00	30.10	+.04	72.0	+0.4	88	7	79	54	19	65	26	66	64	82	3.87	+0.6	10	7,942	ne.	33	ne.	22	10	9	11	5.8	0.0	0.0
Richmond	144	11	52	29.96	30.10	+.03	71.2	+0.7	93	7	82	44	20	61	32	63	60	79	2.41	−0.8	7	4,625	sw.	18	e.	21	17	7	6	4.3	0.0	0.0
Wytheville	2,304	49	55	27.75	30.09	+.02	63.5	−0.1	85	6	74	35	19	53	36	59	57	86	2.72	−0.6	11	2,384	e.	16	sw.	14	11	9	10	5.4	0.0	0.0
South Atlantic States							**73.2**	**−0.2**										**84**	**7.91**	**+3.7**										**6.6**		
Asheville	2,253	70	84	27.77	30.08	+.01	66.4	+1.4	86	5	75	44	20	58	30	60	58	84	9.32	+6.3	14	4,093	se.	18	s.	21	6	11	13	6.4	0.0	0.0
Charlotte	779	55	62	29.25	30.08	+.01	71.2	−0.3	92	6	79	45	20	63	25	65	62	81	3.01	0.0	14	2,862	ne.	15	n.	22	8	8	14	6.2	0.0	0.0
Greensboro	886	5	56	29.16	30.10	------	68.9	------	92	6	79	39	20	59	34	63	62	87	3.11	------	12	4,863	ne.	29	s.	10	8	10	12	5.7	0.0	0.0
Hatteras	11	5	50	30.04	30.05	−.01	74.6	+0.1	86	9	80	60	1	70	21	71	69	85	13.71	+9.1	13	7,942	ne.	36	ne.	21	10	7	13	5.7	0.0	0.0
Raleigh	376	103	110	29.69	30.08	+.01	70.8	−0.3	89	6	79	44	20	63	26	65	63	84	4.12	+0.5	10	4,240	ne.	17	n.	14	9	10	11	5.8	0.0	0.0
Wilmington	78	81	91	29.98	30.06	+.01	73.6	+0.5	87	11	81	51	20	67	21	69	68	87	6.56	+2.0	12	4,108	n.	18	n.	21	8	7	15	6.4	0.0	0.0
Charleston	48	11	92	29.98	30.03	−.01	75.9	−0.7	87	14	81	54	20	71	19	71	70	84	3.86	−0.7	14	7,390	e.	26	ne.	21	4	10	16	7.2	0.0	0.0
Columbia, S. C	351	41	57	29.69	30.06	+.01	73.8	−0.7	92	7	82	49	20	66	21	67	65	82	3.27	−0.2	11	3,984	ne.	18	s.	13	5	14	11	6.4	0.0	0.0
Due West	711	10	55	29.32	30.09	------	71.0	------	92	6	78	47	20	64	25	----	----	----	15.44	------	16	5,378	ne.	24	w.	16	3	13	14	6.6	0.0	0.0
Greenville, S. C	1,039	139	146	28.99	30.07	------	70.4	−0.2	91	6	77	47	20	63	21	65	62	84	12.95	+9.3	18	5,411	ne.	26	ne.	21	8	8	14	6.4	0.0	0.0
Augusta	182	62	77	29.84	30.03	−.02	75.3	0.0	94	6	83	51	20	67	25	68	66	81	11.36	+8.0	12	3,404	ne.	20	nw.	17	3	14	13	7.1	0.0	0.0
Savannah	65	150	194	29.95	30.02	−.01	75.7	−0.5	89	6	82	54	20	70	19	71	70	89	10.31	+4.9	17	6,577	e.	26	e.	29	2	6	22	8.0	0.0	0.0
Jacksonville	43	209	245	29.93	29.98	−.02	77.2	−1.1	90	13	83	61	20	72	17	73	71	86	8.58	+1.2	20	6,860	e.	37	se.	30	1	13	16	7.4	0.0	0.0
Florida Peninsula							**81.3**	**+0.6**										**82**	**11.89**	**+4.8**										**6.8**		
Key West	22	10	64	29.86	29.88	−.06	82.4	+0.2	90	19	87	71	8	77	15	76	74	79	5.57	−1.1	15	6,998	se.	66	w.	28	5	16	9	6.0	0.0	0.0
Miami	25	141	168	29.89	29.92	−.06	81.0	+0.9	89	24	86	71	22	76	14	75	73	80	16.82	+8.5	18	7,111	e.	56	e.	28	1	9	20	7.6	0.0	0.0
Tampa	35	79	87	29.90	29.93	−.04	80.5	+0.6	93	15	88	70	21	73	20	74	73	87	13.29	+6.9	22	4,322	ne.	33	e.	29	1	9	20	8.0	0.0	0.0
Titusville	44	5	----	29.89	29.94	------	79.7	------	90	4	86	68	20	73	19	----	----	----	16.03	------	22	------	se.	----	----	----	8	13	9	5.4	0.0	0.0
East Gulf States							**75.3**	**−0.4**										**81**	**7.04**	**+2.8**										**6.1**		
Atlanta	1,173	190	216	28.82	30.04	−.01	71.3	−1.1	88	6	78	51	20	65	20	65	62	80	10.19	+7.2	15	5,687	e.	30	w.	16	2	11	17	7.4	0.0	0.0
Macon	370	78	87	29.63	30.02	−.01	74.2	−0.6	91	6	82	52	20	67	25	68	66	82	5.95	+2.8	12	3,820	ne.	20	se.	3	3	14	13	6.6	0.0	0.0
Thomasville	273	49	58	29.69	29.98	−.03	76.6	−0.2	92	8	84	56	20	69	21	70	69	87	6.53	+1.6	17	2,943	ne.	18	ne.	30	1	8	21	8.1	0.0	0.0
Apalachicola	36	42	49	29.90	29.94	------	77.0	------	87	14	82	60	21	72	18	73	71	83	8.40	+0.3	16	7,201	ne.	59	se.	30	8	6	16	6.8	0.0	0.0
Pensacola	56	149	185	29.89	29.95	−.04	76.8	−1.2	89	11	81	61	21	72	16	72	70	84	8.96	+3.6	12	8,839	ne.	70	ne.	30	7	10	13	6.2	0.0	0.0
Anniston	741	9	57	29.26	30.05	+.02	73.1	+1.8	93	6	82	51	19	64	29	----	----	----	6.00	+2.3	14	2,768	se.	13	se.	16	9	12	9	5.5	0.0	0.0
Birmingham	700	11	48	29.27	30.02	−.01	74.5	−0.3	92	10	84	50	19	65	30	66	64	80	5.98	+2.6	12	3,868	ne.	28	s.	7	8	11	11	5.8	0.0	0.0
Mobile	57	125	161	29.89	29.95	−.05	76.9	−1.2	92	11	84	58	19	70	27	71	69	83	5.26	+0.3	12	6,462	n.	44	n.	30	7	11	12	6.0	0.0	0.0
Montgomery	223	100	112	29.76	30.00	−.02	75.7	−0.6	93	10	84	56	22	68	22	68	65	78	5.42	+2.4	15	4,214	e.	24	e.	11	5	20	5	5.6	0.0	0.0
Corinth	469	6	----	----	----	------	74.4	------	96	6	85	46	19	64	35	----	----	----	7.34	------	12	------	se.	----	----	----	5	20	5	----	0.0	0.0
Meridian	375	87	95	29.59	29.98	−.04	75.0	+0.5	91	5	83	52	19	67	26	68	66	81	4.86	+1.9	10	3,507	ne.	20	ne.	30	7	13	10	6.0	0.0	0.0
Vicksburg	247	65	73	29.72	29.99	−.03	75.8	−0.5	92	1	85	55	19	67	23	68	65	77	0.34	−2.5	4	3,814	n.	20	nw.	13	13	11	6	4.3	0.0	0.0
New Orleans	53	76	84	29.89	29.94	−.04	78.6	−0.6	93	4	85	63	19	72	19	72	69	79	16.57	+11.5	14	3,842	ne.	26	se.	7	9	6	15	4.6	0.0	0.0
West Gulf States							**78.0**	**+0.9**										**72**	**2.52**	**−1.0**										**3.6**		
Shreveport	249	77	93	29.70	29.96	−.04	77.7	+0.8	95	1	88	59	20	68	28	68	65	73	5.62	+2.8	5	3,192	e.	16	se.	2	19	8	3	2.9	0.0	0.0
Bentonville	1,303	11	44	28.65	30.00	−.02	69.8	+0.9	93	4	81	50	10	59	30	----	----	----	3.81	------	9	1,929	s.	12	s.	4	19	6	5	----	0.0	0.0
Fort Smith	457	79	94	29.51	29.98	−.03	74.0	0.0	96	4	84	56	19	64	28	65	60	69	3.52	+0.5	6	3,933	e.	20	w.	4	15	7	8	4.4	0.0	0.0
Little Rock	357	136	153	29.63	30.00	−.03	74.5	+0.4	93	1	84	53	19	65	28	65	60	68	1.43	−1.7	7	4,062	e.	32	nw.	12	13	7	10	5.1	0.0	0.0
Austin	605	136	148	29.30	29.92	------	79.4	+1.1	97	9	91	59	22	68	29	68	64	67	2.63	−0.8	3	3,926	se.	29	n.	13	16	9	5	3.6	0.0	0.0
Brownsville	57	83	109	29.83	29.89	------	81.2	+0.6	93	7	89	68	23	74	21	74	72	81	5.16	−0.4	11	5,193	se.	23	ne.	21	11	15	4	4.4	0.0	0.0
Corpus Christi	20	11	78	29.90	29.92	−.03	81.4	+1.7	94	30	88	70	23	75	20	75	73	79	3.65	−0.8	6	6,875	e.	38	n.	14	14	13	3	3.9	0.0	0.0
Dallas	512	220	227	29.42	29.96	------	77.0	------	95	4	86	60	10	68	23	----	----	----	2.23	−0.5	5	6,705	e.	35	e.	8	24	3	3	2.0	0.0	0.0
Fort Worth	670	106	114	29.24	29.94	−.05	77.8	+0.9	97	1	88	60	10	68	27	66	61	62	2.29	−0.2	7	4,881	se.	23	se.	8	18	4	8	3.6	0.0	0.0
Galveston	54	106	114	29.89	29.95	−.03	80.5	+0.4	90	30	85	69	19	76	14	74	71	77	0.44	−5.1	6	5,882	s.	25	ne.	13	17	10	3	3.4	0.0	0.0
Groesbeck	461	11	56	29.49	29.96	------	77.4	------	96	4	89	58	25	66	32	----	----	----	2.19	−0.8	7	4,987	e.	27	sw.	13	18	7	5	3.3	0.0	0.0
Houston	138	292	314	29.80	29.95	------	80.0	+1.0	97	6	90	61	20	71	25	----	----	----	0.15	−3.9	5	6,483	e.	26	ne.	13	15	10	5	3.7	0.0	0.0
Palestine	510	64	72	29.44	29.96	−.03	77.6	+0.6	95	5	88	59	20	67	30	68	64	71	3.23	+0.3	4	3,624	ne.	26	nw.	8	18	7	5	3.2	0.0	0.0
Port Arthur	34	58	66	29.90	29.94	------	79.9	------	92	30	88	62	20	72	22	72	70	78	1.72	------	7	4,635	e.	25	e.	10	19	7	4	3.2	0.0	0.0
San Antonio	693	119	132	29.21	29.92	−.04	80.3	+1.3	97	9	91	61	22	70	26	69	64	65	2.02	−1.0	3	4,200	ne.	17	se.	5	16	10	4	3.6	0.0	0.0
Taylor	583	55	63	29.38	29.99	+.02	78.8	+1.9	97	8	90	59	22	67	27	----	----	----	0.65	−2.7	2	4,179	s.	16	s.	9	17	10	3	3.3	0.0	0.0

TABLE 1.—*Climatological data for weather bureau stations, September, 1929*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
Ohio Valley and Tennessee							**68.6**	**−0.1**										**76**	**3.57**	**+0.6**										**5.3**		
Chattanooga	762	190	215	29.23	30.03	−0.03	72.0	−0.2	91	7	80	57	19	64	26	65	61	75	5.66	+2.6	10	3,691	ne.	21	se.	5	5	14	11	6.0	0.0	0.0
Knoxville	995	102	111	29.02	30.05	−.01	71.0	+0.4	91	8	80	47	19	62	28	64	61	77	4.39	+1.7	14	3,333	ne.	19	sw.	8	8	11	11	5.5	0.0	0.0
Memphis	399	76	97	29.58	30.00	−.03	73.8	+0.2	91	3	82	51	19	66	24	66	63	75	1.62	−1.2	8	3,355	e.	18	sw.	5	6	15	9	5.5	0.0	0.0
Nashville	546	168	191	29.48	30.06	.00	71.6	−0.2	92	6	81	48	19	62	30	64	60	75	4.85	+1.4	11	4,320	s.	28	nw.	9	8	8	14	5.9	0.0	0.0
Lexington	989	193	230	29.02	30.08	+.01	68.2	−0.3	90	2	77	40	19	59	29	----	----	----	4.35	+1.3	13	6,983	sw.	24	n.	29	12	11	7	4.7	0.0	0.0
Louisville	525	188	234	29.50	30.08	+.02	69.2	−1.3	91	2	78	43	19	61	34	62	60	78	3.21	+0.4	12	5,028	n.	32	w.	13	11	10	9	4.9	0.0	0.0
Evansville	431	76	116	29.61	30.07	+.01	69.8	−0.9	92	3	78	46	19	62	27	63	60	78	6.50	+3.2	12	3,877	ne.	26	w.	16	13	7	10	4.9	0.0	0.0
Indianapolis	822	194	230	29.18	30.07	+.01	66.4	−0.5	90	2	75	42	19	58	33	58	54	72	2.03	−1.4	9	6,025	e.	29	w.	5	14	6	10	4.8	0.0	0.0
Royal Center	736	11	55	29.29	30.09	------	63.8	------	90	2	74	35	19	53	37	----	----	----	2.81	−0.1	9	5,300	e.	28	sw.	9	12	7	11	5.0	0.0	0.0
Terre Haute	575	96	129	29.44	30.06	------	66.8	------	91	3	76	40	19	57	34	59	56	75	2.72	−0.9	10	4,830	s.	32	sw.	9	13	4	13	5.1	0.0	0.0
Cincinnati	627	11	51	29.40	30.08	+.01	67.1	0.0	92	2	77	39	19	57	33	60	57	78	5.17	+2.5	12	3,347	ne.	20	se.	16	12	8	10	5.0	0.0	0.0
Columbus	822	179	222	29.22	30.09	+.02	66.3	−0.2	91	3	75	40	19	57	27	59	56	76	2.28	−0.3	14	5,034	e.	32	nw.	5	11	9	10	5.0	0.0	0.0
Dayton	899	137	173	29.13	30.07	------	66.3	−0.3	91	2	76	40	19	57	33	59	56	76	3.04	+0.1	13	4,310	ne.	23	ne.	30	8	11	11	5.7	0.0	0.0
Elkins	1,947	59	67	28.09	30.12	+.04	62.9	−0.1	87	6	76	32	19	50	40	56	54	85	3.28	+0.1	10	2,135	nw.	24	w.	14	10	7	13	5.5	0.0	0.0
Parkersburg	637	77	82	29.45	30.11	+.03	68.0	+0.7	92	3	79	40	19	57	36	60	57	76	4.12	+1.4	11	2,497	se.	28	nw.	29	11	7	12	5.6	0.0	0.0
Pittsburgh	842	353	410	29.20	30.10	+.02	67.1	+0.7	90	5	76	40	19	58	28	59	54	67	1.05	−1.5	9	4,739	e.	32	w.	10	10	8	12	5.3	0.0	0.0
Lower Lake Region							**64.2**	**+1.2**										**74**	**2.62**	**−0.4**										**5.1**		
Buffalo	767	247	280	29.25	30.08	+.02	63.1	+0.7	86	5	70	37	20	56	22	59	56	83	3.25	+0.3	8	8,995	sw.	54	sw.	10	12	7	11	4.8	0.0	0.0
Canton	448	10	61	29.60	30.07	------	61.2	+1.9	91	5	71	25	21	51	36	----	----	----	2.51	−0.8	8	5,567	sw.	39	sw.	10	16	6	8	4.3	0.0	0.0
Ithaca	836	5	100	29.20	30.10	------	62.8	------	92	4	73	29	20	52	34	56	54	81	2.42	−0.6	11	4,794	nw.	26	s.	16	11	5	14	5.7	0.0	0.0
Oswego	335	76	91	29.72	30.08	+.02	63.4	+2.2	89	5	71	38	20	56	27	57	53	72	3.16	+0.4	12	5,154	s.	24	sw.	10	9	10	11	5.4	0.0	0.0
Rochester	523	86	102	29.53	30.10	+.04	64.6	+2.2	94	5	74	36	20	56	30	56	51	69	2.87	+0.4	7	4,651	sw.	35	w.	10	12	4	14	5.0	0.0	0.0
Syracuse	596	65	79	29.46	30.11	+.04	65.2	+3.6	93	4	74	35	21	56	31	----	----	----	3.90	+1.2	11	3,767	s.	20	nw.	11	10	10	10	5.5	0.0	0.0
Erie	714	130	166	29.32	30.09	+.03	65.2	+1.6	87	5	72	40	19	58	27	58	54	70	1.89	−1.5	12	7,701	n.	34	sw	10	14	3	13	4.9	0.0	0.0
Cleveland	762	267	337	29.27	30.09	+.03	65.6	+1.7	90	5	73	44	20	58	26	58	53	68	1.62	−1.7	12	7,656	s.	35	w.	10	13	4	13	5.2	0.0	0.0
Sandusky	629	5	67	29.42	30.10	+.04	65.6	+0.3	94	3	74	42	15	57	33	----	----	----	2.53	−0.4	12	4,593	s.	21	w.	10	10	10	10	5.6	0.0	0.0
Toledo	628	208	243	29.42	30.10	+.04	64.2	−0.2	90	3	73	42	18	56	31	57	53	74	3.21	+0.4	12	7,131	e.	36	w.	5	12	8	10	4.7	0.0	0.0
Fort Wayne	856	113	124	29.16	30.08	------	63.8	−1.7	90	3	73	38	19	54	34	57	53	76	2.35	−0.7	11	4,733	ne.	23	w.	16	11	8	11	5.1	0.0	0.0
Detroit	730	218	258	29.31	30.10	+.04	64.8	+1.3	90	3	73	42	18	56	25	57	54	74	1.75	−1.2	10	5,714	sw.	31	sw.	13	11	12	7	4.7	0.0	0.0
Upper Lake Region							**59.3**	**−0.3**										**75**	**2.48**	**−0.9**										**5.4**		
Alpena	609	13	92	29.42	30.08	+.05	57.6	0.0	96	3	67	30	19	48	32	53	49	78	1.90	−1.1	8	6,345	nw.	35	w.	10	12	7	11	5.2	0.0	0.0
Escanaba	612	54	60	29.39	30.05	+.04	55.8	−1.3	79	3	63	34	18	49	22	51	48	78	2.04	−1.3	12	6,632	s	28	nw.	10	10	13	7	5.2	0.0	0.0
Grand Haven	632	54	89	29.39	30.07	+.03	60.6	−0.3	84	4	70	36	19	51	29	54	50	73	0.88	−2.8	6	6,486	s.	36	w.	10	10	12	8	4.9	0.0	0.0
Grand Rapids	707	70	87	29.32	30.08	+.03	62.9	+0.2	91	3	74	36	19	52	32	54	49	68	0.99	−2.5	7	3,304	w.	24	nw.	10	9	4	17	6.2	0.0	0.0
Houghton	668	64	99	29.29	30.02	+.02	56.2	−0.7	94	2	64	38	17	48	31	----	----	----	3.60	0.0	13	5,816	e.	25	w.	10	6	10	14	6.5	0.0	0.0
Lansing	878	6	49	29.14	30.08	------	61.4	0.0	92	2	73	32	19	49	34	55	52	81	1.23	−1.7	8	2,839	s.	18	w.	10	11	9	10	5.3	0.0	0.0
Ludington	637	60	66	29.37	30.06	------	58.9	−0.4	81	2	67	35	19	51	29	53	50	77	2.88	−0.4	12	6,436	s.	33	w.	10	13	11	6	4.1	0.0	0.0
Marquette	734	77	111	29.23	30.04	+.04	57.3	−0.2	96	3	65	36	18	50	33	50	47	75	3.79	+0.5	15	7,352	nw.	37	sw.	15	6	10	14	6.4	0.0	0.0
Port Huron	638	70	120	29.39	30.08	+.02	62.5	+0.9	92	3	72	37	18	53	28	55	51	72	1.16	−1.7	7	6,476	sw.	31	w.	10	9	15	6	4.4	0.0	0.0
Sault Ste. Marie	614	11	52	29.37	30.07	+.05	56.4	+0.9	89	4	65	33	19	48	32	50	47	79	2.92	−1.3	13	4,690	nw.	30	nw.	10	12	6	12	6.1	0.0	0.0
Chicago	673	7	131	29.35	30.07	+.03	64.6	−0.6	91	2	72	42	18	57	28	57	52	72	3.03	−0.1	8	6,169	s.	25	sw.	13	11	8	11	4.9	0.0	0.0
Green Bay	617	109	141	29.38	30.04	+.02	59.8	−0.6	92	3	69	35	18	51	29	53	49	74	2.38	−1.1	9	6,959	s.	32	s.	15	8	9	13	6.0	0.0	0.0
Milwaukee	681	125	221	29.33	30.06	+.03	62.3	−0.2	93	2	70	37	18	55	25	55	51	71	3.15	−0.1	7	8,633	sw.	33	sw.	15	13	5	12	4.9	0.0	0.0
Duluth	1,133	5	47	28.80	30.02	+.04	53.8	−1.3	90	2	63	28	19	45	31	47	44	77	4.82	+1.5	13	7,923	nw.	31	nw.	4	11	7	12	5.7	0.0	0.0
North Dakota							**52.7**	**−4.5**										**68**	**1.60**	**0.0**										**6.1**		
Moorhead	940	50	58	28.99	30.01	+.05	54.8	−3.4	93	1	65	24	18	44	35	47	42	68	0.91	−1.3	9	5,066	s.	23	s.	21	7	7	16	6.5	0.0	0.0
Bismarck	1,674	8	57	28.22	30.01	+.07	53.1	−5.0	102	1	64	30	18	43	46	46	40	69	1.69	+0.5	6	4,859	nw.	25	sw.	14	7	12	11	6.0	0.0	0.0
Devils Lake	1,478	11	44	28.42	30.00	+.06	50.8	−5.1	100	1	61	23	18	40	38	44	39	71	2.73	+1.1	6	5,051	s.	24	ne.	2	7	10	13	6.1	0.0	0.0
Ellendale	1,457	10	56	28.45	30.02	------	53.4	------	94	1	65	20	18	42	38	----	----	----	1.40	−0.6	11	7,602	nw.	33	nw.	3	4	9	17	6.9	0.0	0.0
Grand Forks	833	12	67	----	----	----	53.6	------	95	1	65	18	18	42	40	47	----	----	1.49	------	6	------	nw.	----	s.	15	14	10	6	----	0.0	0.0
Williston	1,878	41	48	28.02	30.01	+.08	52.2	−4.4	96	1	63	31	8	42	38	45	38	66	1.25	+0.2	9	3,973	nw.	24	nw.	3	10	13	7	5.1	0.0	0.0
Upper Mississippi Valley							**63.7**	**−1.5**										**74**	**3.18**	**−0.5**										**5.0**		
Minneapolis	918	102	208	29.02	30.00	------	59.0	−2.4	95	3	67	32	18	51	26	----	----	----	3.57	+0.4	12	7,290	s.	31	s.	23	8	8	14	6.2	0.0	0.0
St. Paul	837	236	261	29.11	30.02	+.03	58.4	−2.9	93	2	67	32	18	50	29	----	----	----	3.36	+0.3	9	7,479	se.	35	sw.	3	7	10	13	6.3	0.0	0.0
La Crosse	714	11	48	29.27	30.04	+.03	61.2	−1.0	96	2	72	32	18	50	33	54	51	79	4.33	+0.3	10	2,742	s.	14	s.	15	11	11	8	4.9	0.0	0.0
Madison	974	70	78	29.03	30.07	+.04	60.6	−1.8	91	2	70	37	18	52	30	54	49	73	3.17	−0.6	8	5,014	s.	22	s.	15	11	13	6	4.3	0.0	0.0
Wausau	1,247	4	64	28.72	30.05	------	58.6	------	95	3	70	31	18	48	34	----	----	----	2.24	−1.5	9	3,885	s.	22	sw.	4	10	13	7	5.0	0.0	0.0
Charles City	1,015	10	51	28.97	30.05	+.05	60.4	−0.6	93	2	71	29	18	50	32	53	49	74	3.96	+0.3	10	4,201	se.	22	sw.	2	14	8	8	4.2	0.0	0.0
Davenport	606	71	79	29.38	30.04	+.01	64.6	−1.0	92	2	74	35	18	55	30	57	52	70	3.13	−0.4	11	5,140	s.	30	s.	4	11	7	12	5.2	0.0	0.0
Des Moines	861	84	97	29.12	30.02	.00	63.8	−1.8	92	2	74	37	18	54	30	56	52	72	4.67	+1.0	9	4,322	s.	25	sw.	15	8	12	10	5.1	0.0	0.0
Dubuque	700	81	96	29.30	30.05	+.02	62.6	−1.4	91	2	72	35	18	53	33	55	50	69	1.55	−2.5	7	3,792	s.	20	s.	15	13	6	11	5.0	0.0	0.0
Keokuk	614	64	78	29.38	30.05	+.02	65.4	−2.1	92	2	75	42	18	56	29	58	54	72	4.77	+0.9	10	3,901	s.	27	sw.	4	12	10	8	5.0	0.0	0.0
Cairo	358	87	93	29.66	30.03	−.02	70.0	−1.5	89	1	78	48	19	62	25	64	61	81	5.44	+2.6	11	3,894	ne.	28	n.	29	9	10	11	5.6	0.0	0.0
Peoria	609	11	45	29.41	30.07	+.03	65.2	+0.9	92	2	76	35	18	55	32	57	53	76	1.04	−3.0	7	3,352	s.	17	sw.	4	15	8	7	4.2	0.0	0.0
Springfield, Ill.	636	154	191	29.38	30.05	.00	65.4	−2.2	92	2	75	38	18	56	29	58	55	75	1.65	−2.0	8	6,870	s.	30	n.	29	12	7	11	4.9	0.0	0.0
Hannibal	534	74	109	29.48	30.05	+.02	66.4	−1.3	94	2	76	43	18	57	29	----	----	----	3.18	−0.8	8	4,694	s.	31	sw.	4	12	9	9	4.9	0.0	0.0
St. Louis	568	265	303	29.44	30.04	.00	68.7	−1.4	92	2	77	46	19	60	24	61	56	72	1.71	−1.8	11	6,158	s.	32	n.	29	12	9	9	4.6	0.0	0.0
Missouri Valley							**63.3**	**−2.7**										**71**	**2.31**	**−0.8**										**5.3**		
Columbia, Mo	784	6	84	29.21	30.03	.00	66.9	−1.3	96	2	76	44	18	58	29	----	----	----	3.06	−1.3	9	4,021	se.	27	sw.	4	13	7	10	4.9	0.0	0.0
Kansas City	963	161	181	28.98	30.01	−.01	67.8	−1.1	93	2	77	45	18	59	30	59	54	67	1.55	−3.0	11	5,723	s.	22	nw.	9	12	11	7	4.8	0.0	0.0
St. Joseph	967	11	49	28.98	30.01	------	66.6	------	94	2	77	43	18	56	29	58	53	72	1.94	−1.9	10	4,642	se.	22	nw.	13	9	13	8	4.9	0.0	0.0
Springfield, Mo	1,324	98	104	28.64	30.04	+.01	68.5	−0.4	89	2	77	50	10	60	23	60	57	73	2.37	−1.2	8	5,503	se.	24	se.	19	16	7	7	3.9	0.0	0.0
Iola	984	11	50	28.97	30.00	−.01	68.9	−0.9	94	2	81	43	10	57	37	----	----	----	1.86	−3.1	11	3,266	s.	16	s.	15	13	7	10	4.7	0.0	0.0
Topeka	987	92	107	----	----	----	67.6	−1.1	94	2	78	46	10	57	30	----	----	----	1.49	−2.3	6	5,637	s.	36	se.	19	12	11	7	4.8	0.0	0.0
Lincoln	1,189	11	81	28.75	30.00	+.01	64.6	−1.8	98	2	75	42	18	54	34	55	50	68	1.82	−1.2	8	6,489	s.	24	n.	29	8	11	11	5.6	0.0	0.0
Omaha	1,105	115	122	28.84	30.02	+.02	63.6	−3.2	95	2	73	41	18	54	29	56	51	70	2.05	−1.2	13	4,969	s.	26	nw.	6	14	7	9	4.8	0.0	0.0
Valentine	2,598	47	54	27.32	30.02	+.06	56.6	−5.9	98	2	67	24	6	46	42	49	44	70	2.10	+0.8	16	5,206	n.	34	s.	22	8	9	13	6.0	T.	0.0
Sioux City	1,135	94	164	28.81	30.02	+.04	60.6	−2.8	96	2	70	34	18	52	32	54	49	74	3.18	+0.2	10	7,765	se.	39	s.	23	6	12	12	6.0	0.0	0.0
Huron	1,306	59	74	28.63	30.04	+.08	57.1	−4.2	104	2	67	30	18	47	37	50	45	72	2.79	+1.2	12	5,865	se.	28	s.	2	6	10	14	6.7	0.0	0.0
Pierre	1,572	70	75	----	----	----	58.1	−5.7	104	1	68	37	18	48	44	----	----	----	1.28	+0.2	11	----	----	----	----	----	9	8	13	----	0.0	0.0
Yankton	1,233	49	57	28.69	30.00	+.02	59.8	−4.2	99	2	70	35	18	50	34	----	----	----	4.57	+1.8	11	4,726	nw.	28	s.	23	5	9	16	6.9	0.0	0.0

TABLE 1.—*Climatological data for weather bureau stations, September, 1929*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	°*F.*		°*F.*	°*F.*		°*F.*	°*F.*	°*F.*	°*F.*	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
Northern Slope							**53.0**	**−4.4**										**65**	**1.54**	**+0.3**										**5.3**		
Billings	3,140	5					54.4		97	1	69	24	8	40	52				1.66		10		nw.				8	8	14		0.0	0.0
Havre	2,505	11	44	27.40	30.04	+.10	52.4	−4.0	83	1	66	24	6	39	44	44	36	61	1.46	+0.2	8	3,456	sw.	32	n.	14	11	8	11	5.0	0.0	0.0
Helena	4,110	87	112	25.84	30.04	+.07	50.7	−5.9	82	1	62	30	7	40	37	42	34	59	1.57	+0.3	10	4,486	sw.	34	nw.	14	12	7	11	5.1	T.	0.0
Kalispell	2,973	48	56	26.96	30.00	+.04	51.6	−1.9	82	17	64	28	29	39	41	42	33	57	0.51	−0.7	6	3,482	nw.	27	ne.	4	12	10	8	4.4	0.0	0.0
Miles City	2,371	48	55	27.50	30.05	+.10	55.4	−5.8	100	1	66	33	7	45	44	46	38	62	1.86	+0.8	9	3,211	nw.	29	nw.	21	13	6	11	5.3	0.0	0.0
Rapid City	3,259	50	58	26.65	30.06	+.10	54.2	−6.2	99	1	64	34	6	44	42	47	40	66	1.80	+0.6	11	4,467	n.	30	n.	14	11	7	12	5.7	T.	0.0
Cheyenne	6,088	84	101	24.05	29.97	+.01	53.0	−4.0	89	1	64	28	9	42	41	45	39	69	1.81	+0.6	13	6,264	w.	41	w.	23	10	10	10	5.5	0.8	0.0
Lander	5,372	60	68	24.67	30.00	+.04	53.6	−2.1	90	1	66	31	8	41	44	45	39	68	1.82	+0.9	11	2,753	sw.	34	sw.	23	11	11	8	4.9	4.0	0.0
Sheridan	3,790	10	47	26.13	30.02		53.0		94	1	66	28	9	41	54	45	39	68	1.15	−0.1	13	2,509	nw.	25	sw.	21	12	8	10	5.9	0.0	0.0
Yellowstone Park	6,241	11	48	23.92	30.02	+.05	46.8	−6.6	79	1	59	25	8	35	39	38	31	64	1.17	−0.1	11	4,192	sw.	28	nw.	15	8	11	11	5.6	4.5	0.0
North Platte	2,821	11	51	27.09	29.99	+.02	59.2	−2.9	96	1	70	36	10	48	39	51	46	72	2.22	+0.9	10	4,572	ne.	26	n.	15	9	11	10	5.6	0.0	0.0
Middle Slope							**66.2**	**−1.8**										**64**	**2.02**	**−0.2**										**4.2**		
Denver	5,292	106	113	24.76	29.96	.00	58.8	−4.1	93	1	70	34	6	48	35	49	43	63	1.34	+0.4	8	4,241	n.	22	nw.	5	11	11	8	4.6	T.	0.0
Pueblo	4,685	80	86	25.27	29.89	−.07	63.8	−0.8	92	1	77	42	16	51	40	51	43	57	0.51	−0.2	8	3,775	e.	32	w.	3	13	11	6	4.2	0.0	0.0
Concordia	1,392	50	58	28.55	30.01	+.02	65.8	−2.5	96	2	76	45	5	55	34	56	51	66	2.96	+0.4	13	5,079	s.	26	s.	19	11	10	9	5.2	0.0	0.0
Dodge City	2,509	11	51	27.42	29.99	+.01	66.8	−2.6	100	1	79	44	10	54	38	56	50	65	2.61	+0.7	7	6,481	s.	27	se.	3	19	6	5	3.1	0.0	0.0
Wichita	1,358	139	158	28.56	29.97	−.03	69.6	−1.0	94	2	80	47	10	59	30	59	53	65	0.98	−2.1	8	7,671	s.	36	sw.	15	14	10	6	4.4	0.0	0.0
Broken Arrow	765	11	56	29.18	30.00		71.2		95	1	82	52	10	61	29				3.07	−0.5	7	6,441	s.	26	n.	29	15	5	10	4.2	0.0	0.0
Oklahoma City	1,214	10	47	28.72	29.97	−.02	72.7	−0.1	97	1	83	52	10	62	32	63	59	70	2.69	−0.4	7	5,507	s.	30	nw.	7	17	3	10	3.9	0.0	0.0
Southern Slope							**73.7**	**+0.2**										**62**	**2.05**	**−0.4**										**3.9**		
Abilene	1,738	10	52	28.17	29.95	−.01	75.6	+0.3	97	4	86	55	10	65	29	63	57	63	4.37	+1.7	6	5,231	se.	23	s.	4	15	7	8	3.9	0.0	0.0
Amarillo	3,676	10	49	26.29	29.96	.00	68.2	−1.1	93	3	80	47	11	57	31	58	52	66	1.97	−0.3	10	6,020	s.	22	n.	9	15	8	7	4.6	0.0	0.0
Del Rio	944	64	71	28.91	29.88	−.06	80.2	+1.0	98	4	90	64	21	71	25	69	63	62	1.47	−1.5	8	5,366	se.	22	se.	8	18	7	5	3.7	0.0	0.0
Roswell	3,566	75	85	26.36	29.90	−.02	70.9	+0.6	93	2	84	52	10	58	35	59	51	58	0.42	−1.7	4	4,323	s.	32	ne.	15	17	10	3	3.4	0.0	0.0
Southern Plateau							**72.3**	**+1.5**										**54**	**1.42**	**+0.6**										**2.7**		
El Paso	3,778	152	175	26.15	29.84	−.04	76.6	+2.7	93	2	87	59	11	66	29	60	50	45	0.12	−1.1	3	6,225	e.	33	w.	21	20	7	3	3.2	0.0	0.0
Santa Fe	7,013	38	53	23.32	29.89	−.04	60.6	−0.3	83	2	72	43	14	49	32	50	43	62	5.15	+3.7	8	3,465	se.	24	nw.	15	11	15	4	3.9	0.0	0.0
Flagstaff	6,907	10	59	23.39	29.83	−.06	58.8	+3.3	83	15	71	36	13	46	42	48		61	0.74				sw.		sw.	22	7	17	6		0.0	0.0
Phoenix	1,108	10	107	28.62	29.74	−.07	84.0	+1.3	107	14	97	65	8	71	41	66	57	47	0.19	−0.6	3	3,166	se.	20	se.	17	20	8	2	2.4	0.0	0.0
Yuma	141	9	54	29.59	29.72	−.06	84.0	+0.3	111	14	98	61	23	70	42	69	60	53	1.47	+1.1	3	2,351	sw.	25	ne.	2	25	3	2	1.4	0.0	0.0
Independence	3,957	6	27	25.90	29.86	.00	69.8	+1.8	99	1	87	41	23	52	49	49			0.19	+0.1	2		nw.				26	0	4		0.0	0.0
Middle Plateau							**60.9**	**−1.0**										**43**	**1.04**	**+0.4**										**2.6**		
Reno	4,532	74	81	25.42	29.86	−.09	61.2	+1.5	96	17	79	31	27	43	49	45	31	37	0.03	−0.2	2	3,872	w.	24	s.	20	24	6	0	1.2	0.0	0.0
Tonopah	6,090	12	20				63.2		86	1	74	40	27	52	29	46	27	30	0.40		4		se.									
Winnemucca	4,344	18	56	25.59	29.94	+.01	57.0	−2.2	97	17	77	26	28	37	55	42	27	36	0.06	−0.4	1	3,619	ne.	19	nw.	20	27	3	0	1.4	0.0	0.0
Modena	5,473	10	43	24.59	29.85	−.07	60.0	0.0	88	14	76	32	29	44	47	47	34	46	0.49	−0.3	1	6,455	sw.	36	sw.	27	17	10	3	2.8	0.0	0.0
Salt Lake City	4,360	163	203	25.58	29.90	−.05	61.8	−2.6	88	18	72	43	9	52	33	51	44	54	2.45	+1.5	8	4,580	nw.	30	w.	3	17	5	8	3.9	0.0	0.0
Grand Junction	4,602	60	68	25.36	29.90	−.05	64.7	−1.5	87	1	76	42	9	53	34	52	43	54	2.16	+1.2	13	4,294	se.	26	s.	22	16	10	4	3.6	0.0	0.0
Northern Plateau							**58.4**	**−2.2**										**46**	**0.48**	**−0.4**										**3.8**		
Baker	3,471	48	53	26.46	30.04	+.05	53.3	−2.7	90	17	68	27	29	38	46	42	30	46	0.28	−0.5	2	3,334	se.	18	nw.	3	16	9	5	3.5	0.0	0.0
Boise	2,739	78	86	27.14	29.98	+.01	58.8	−3.1	94	17	72	34	29	46	41	47	35	46	0.26	−0.3	4	2,735	w.	18	w.	2	19	9	2	2.5	0.0	0.0
Lewiston	757	40	48	29.19	30.00	+.02	61.2	−1.6	96	13	75	37	30	47	44				0.39	−0.6	4	1,642	e.	17	nw.	1	9	5	16	4.6	0.0	0.0
Pocatello	4,477	60	68	25.46	29.94	−.02	56.6	−3.6	88	17	70	30	29	44	37	44	32	45	1.21	+0.4	5	4,006	se.	27	sw.	2	14	9	7	3.9	T.	0.0
Spokane	1,929	101	110	27.98	30.02	+.04	57.8	−1.4	90	13	71	32	30	45	38	47	36	49	0.30	−0.6	5	2,855	s.	18	n.	9	10	13	7	4.7	0.0	0.0
Walla Walla	991	57	65	28.93	29.99	−.01	63.0	−0.8	93	13	75	40	29	51	33	50	36	43	0.47	−0.5	4	2,429	s.	19	w.	20	17	6	6	3.7	0.0	0.0
North Pacific Coast Region							**60.0**	**+1.8**										**65**	**0.17**	**−2.0**										**3.4**		
North Head	211	11	56	29.81	30.03	.00	58.6	+2.1	83	16	64	49	26	53	30	55	52	82	0.45	−2.5	5	6,704	n.	30	n.	20	17	7	7	3.7	0.0	0.0
Port Angeles	29	8	53		30.06		56.6		80	5	66	37	24	47	32				0.18	−1.3	3	2,649	sw.	19	w.	1	17	10	3		0.0	0.0
Seattle	125	215	250	29.88	30.02	+.01	60.8	+2.7	81	13	70	43	27	52	27	54	48	66	0.09	−1.7	4	3,128	n.	17	ne.	20	21	2	7	2.9	0.0	0.0
Tacoma	194	172	201	29.82	30.02	.00	60.0	+2.7	81	10	70	41	27	50	29				0.08	−2.0	2	3,770	n.	23	n.	25	15	7	8	4.5	0.0	0.0
Tatoosh Island	86	9	53	29.93	30.03	+.02	54.6	+1.6	73	13	60	43	28	49	21	52	50	88	0.07	−4.6	4	6,180	ne.	41	ne.	16	12	8	10	4.8	0.0	0.0
Yakima	1,076	58	67	28.86	30.01		61.6		92	14	75	35	21	48	40	50	39	48	0.17	−0.3	2	3,035	nw.	22	nw.	20	18	6	6	3.5	0.0	0.0
Medford	1,425	4	80	28.44	29.93		61.4		99	16	82	31	28	41	53	51	40	56	T.		0		se.	15	n.	4	21	6	3	2.0	0.0	0.0
Portland, Oreg	153	68	106	29.84	30.00	−.03	64.8	+3.1	87	16	76	45	27	54	31	55	47	59	0.31	−1.7	3	3,165	nw.	18	ne.	29	16	9	5	3.2	0.0	0.0
Roseburg	510	75	99	29.42	29.97	−.05	61.4	−1.5	92	13	77	35	27	46	43	51	41	56	0.03	−1.2	1	1,883	n.	17	n.	2	17	10	3	2.8	0.0	0.0
Middle Pacific Coast Region							**65.3**	**+0.5**										**62**	T.	**−0.6**										**2.4**		
Eureka	62	73	89	29.90	29.97	−.04	55.6	−0.3	72	11	61	44	30	50	21	53	52	89	0.00	−1.0	0	3,264	n.	23	nw.	2	11	7	12	5.2	0.0	0.0
Red Bluff	330	5	58	29.48	29.82	−.11	73.9	+0.8	107	15	90	46	30	58	43	54	36	30	0.00	−0.8	0	3,119	nw.	18	n.	21	26	4	0	1.0	0.0	0.0
Sacramento	69	106	117	29.75	29.82	−.07	70.4	+1.1	102	15	86	47	27	55	42	57	47	52	0.00	−0.4	0	4,064	s.	21	sw.	18	29	1	0	0.3	0.0	0.0
San Francisco	155	208	243	29.71	29.88	−.06	61.4	+0.5	79	14	68	51	29	55	25	56	53	79	T.	−0.4	0	4,165	w.	24	w.	9	17	8	5	3.6	0.0	0.0
San Jose	141	12	110	29.73	29.88		65.2	+0.5	93	14	79	42	25	51	39				0.00	−0.4	0	3,495	nw.	24	sw.	18	24	6	0	1.8	0.0	0.0
South Pacific Coast Region							**70.9**	**+1.1**										**64**	**0.20**	**+0.1**										**4.6**		
Fresno	327	89	98		29.82	−.05	74.4	+1.0	103	16	90	48	28	59	39			39	0.01	−0.2	1	3,705	nw.	17	s.	18	27	2	1		0.0	0.0
Los Angeles	338	159	191	29.50	29.86	−.02	70.2	+1.2	99	17	78	55	29	62	33	62	58	72	0.32	+0.2	2	3,054	sw.	17	se.	17	17	5	8	3.9	0.0	0.0
San Diego	87	62	70	29.76	29.84	−.05	68.2	+1.1	95	17	73	57	30	63	31	63	60	81	0.26	+0.2	3	3,730	nw.	26	se.	17	11	12	7	5.2	0.0	0.0
West Indies																																
San Juan, P. R.	82	9	54	29.84	29.92		79.9	−0.6	88	18	85	69	16	75	13				5.84	−1.0	22	5,787	e.	48	n.	16	1	20	9	6.1	0.0	0.0
Panama Canal																																
Balboa Heights	118	7	97	[1]29.74	[1]29.83	+.01	79.3	−0.5	91	4	85	71	27	74	17			[2]88	9.26	+1.3	21	3,487	s.	27	ne.	23	0	7	23	8.3	0.0	0.0
Cristobal	38	7	97	[1]29.79	[1]29.82	−.01	81.6	+1.2	92	22	88	72	16	75	18	76	75	[2]83	7.90	−4.5	19	4,123	s.	22	n.	9	0	12	18	8.0	0.0	0.0
Alaska																																
Juneau	80	11	50	[1]30.03	[1]30.12		52.2		66	9	58	38	22	47	23	50	49	89	5.52		15	3,153	w.	29	e.	13	4	8	18	7.6	0.0	0.0
Hawaiian Islands																																
Honolulu	38	86	100	[1]29.94	[1]29.98		79.3		88	9	84	71	8	74	16	71	68	69	1.35	+0.1	15	4,930	e.	22	e.	28	14	13	3	4.1	0.0	0.0

[1] Pressure not reduced to mean of 24 hours.

[2] Observations taken bihourly.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, September, 1929*

Stations	Altitude above mean sea level Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	°F.	°F.	°F.	°F.	°F.	°F.	*Inches*	*Inches*	*Inches*
Cape Race, N. F.	99				53.8		60.2	47.5	70	37	2.17		0.0
Sydney, C. B. I.	48												
Halifax, N. S.	88												
Yarmouth, N. S.	65												
Charlottetown, P. E. I.	38												
Chatham, N. B.	28												
Father Point, Que.	20												
Quebec, Que.	296	29.77	30.09	+0.08	56.8	+1.7	64.1	49.5	80	34	3.11	−0.56	0.0
Doucet, Que.	1,236												
Montreal, Que.	187	29.86	30.06	+.02	60.5	+2.1	68.7	52.3	87	37	2.25	−1.05	0.0
Ottawa, Ont.	236	29.82	30.08	+.04	61.8	+4.4	73.8	49.9	97	30	2.18	−0.51	0.0
Kingston, Ont.	285	29.77	30.08	+.04	62.2	+2.2	69.2	55.2	83	36	1.22	−1.58	0.0
Toronto, Ont.	379	29.68	30.08	+.02	62.2	+3.2	71.0	53.4	94	37	0.78	−2.47	0.0
Cochrane, Ont.	930				50.2		59.2	41.3	82	28	3.76		T.
White River, Ont.	1,244	28.69	30.01	+.03	48.5	−1.8	59.4	37.7	85	26	4.71	+1.94	0.0
London, Ont.	808				62.2		73.9	50.6	94	28	1.58		0.0
Southampton, Ont.	656	29.36	30.07	+.02	60.4	+2.9	70.4	50.4	90	30	0.94	−2.00	0.0
Parry Sound, Ont.	688	29.38	30.06	+.03	59.4	+3.4	68.6	50.2	90	34	1.97	−1.70	0.0
Port Arthur, Ont.	644	29.32	30.03	+.05	52.3	+0.1	60.7	43.9	86	30	5.14	+1.66	0.0
Winnipeg, Man.	760												
Minnedosa, Man.	1,690	28.18	30.01	+.07	47.6	−2.9	59.5	35.8	92	18	1.40	+0.04	0.0
Le Pas, Man.	860				47.0		55.6	38.4	75	30	1.95		T.
Qu'Appelle, Sask.	2,115	27.74	29.99	+.07	48.5	−2.6	58.1	38.9	82	28	1.75	+0.42	0.0
Moose Jaw, Sask.	1,759				52.6		63.9	41.3	90	32	0.92		0.0
Swift Current, Sask.	2,392	27.44	29.95	+.03	51.3	−1.8	64.7	37.9	92	24	1.37	+0.15	0.0
Medicine Hat, Alb.	2,144	27.68	29.93	+.01	53.6	−1.4	66.0	41.2	80	25	0.33	−0.85	0.0
Calgary, Alb.	3,428	26.46	30.04	+.12	48.8	−1.0	61.4	36.2	79	23	1.02	−0.34	0.0
Banff, Alb.	4,521	25.43	30.00	+.07	46.5	+0.7	59.1	33.9	77	22	1.32	−0.35	1.1
Prince Albert, Sask.	1,450	28.42	29.99	+.09	49.2	+0.8	59.1	39.4	77	30	1.83	+0.55	0.0
Battleford, Sask.	1,592	28.24	29.97	+.07	50.3	−1.5	61.7	39.0	77	28	1.07	−0.18	0.0
Edmonton, Alb.	2,150	27.67	29.96	+.06	49.1	−0.2	60.3	37.9	74	20	0.34	−0.99	0.0
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.78	30.03	+.02	60.1	+5.3	69.2	51.0	82	45	0.10	−2.06	0.0
Barkerville, B. C.	4,180												
Estevan Point, B. C.	20												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151												

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Father Point, Que.	20	29.81	29.83	−0.08	54.0	−1.6	61.8	46.2	72	42	4.74	+1.69	0.0
Winnipeg, Man.	760	29.14	29.95	+.01	68.3	+4.9	81.9	54.7	100	37	0.55	−2.12	0.0
Qu'Appelle, Sask.	2,115	27.74	29.95	+.02	65.1	+3.6	80.4	49.8	93	36	0.23	−1.41	0.0
Swift Current, Sask.	2,392	27.43	29.89	−.04	68.2	+4.2	86.4	50.1	100	35	0.48	−1.43	0.0
Medicine Hat, Alb.	2,144	27.63	29.83	−.09	72.8	+7.1	87.9	57.8	100	45	0.21	−1.46	0.0
Calgary, Alb.	3,428	26.43	29.93	+.02	63.2	+3.8	79.7	46.7	93	34	0.67	−1.47	0.0
Banff, Alb.	4,521	25.44	29.93	+.02	59.1	+2.8	75.7	42.5	90	31	0.82	−1.71	0.0
Battleford, Sask.	1,592	28.20	29.91	.00	65.5	+2.9	81.1	49.9	94	37	0.30	−2.06	0.0
Edmonton, Alb.	2,150	27.64	29.88	−.04	60.2	+1.4	73.8	46.7	86	38	2.27	+0.14	0.0
Kamloops, B. C.	1,262	28.66	29.92	+.01	70.0	+1.4	83.3	56.7	92	44	0.37	−0.72	0.0
Estevan Point, B. C.	20				56.9		62.6	51.2	66	48	6.02		0.0
Prince Rupert, B. C.	170				57.4		63.3	51.5	84	46	7.00		0.0
Hamilton, Ber.	151	30.00	30.16	+.06	78.8	−0.8	84.5	73.1	88	69	13.60	+7.52	0.0

Chart I. Departure (°F.) of the Mean Temperature from the Normal, September, 1929

Chart I. Departure (°F.) of the Mean Temperature from the Normal, September, 1929

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Chart II. Tracks of Centers of Anticyclones, September, 1929. (Inset) **Departure of Monthly Mean Pressure from Normal**

(Plotted by Wilfred P. Day)

Chart III. Tracks of Centers of Cyclones, September, 1929. (Inset) **Change in Mean Pressure from Preceding Month**

(Plotted by Wilfred P. Day)

Chart III. Tracks of Centers of Cyclones, September, 1929. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Wilfred P. Day.)

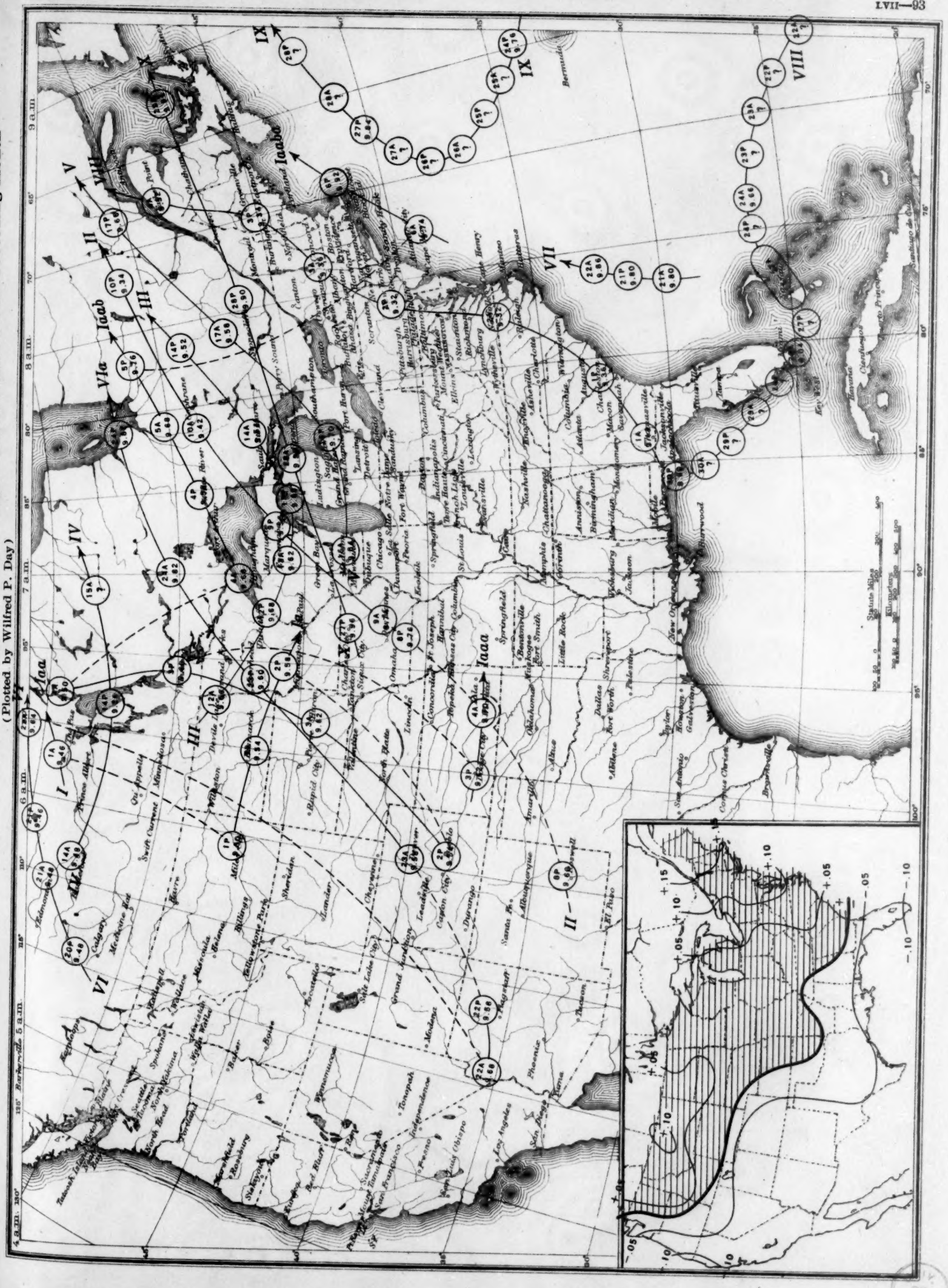


Chart IV. Percentage of Clear Sky between Sunrise and Sunset, September, 1929

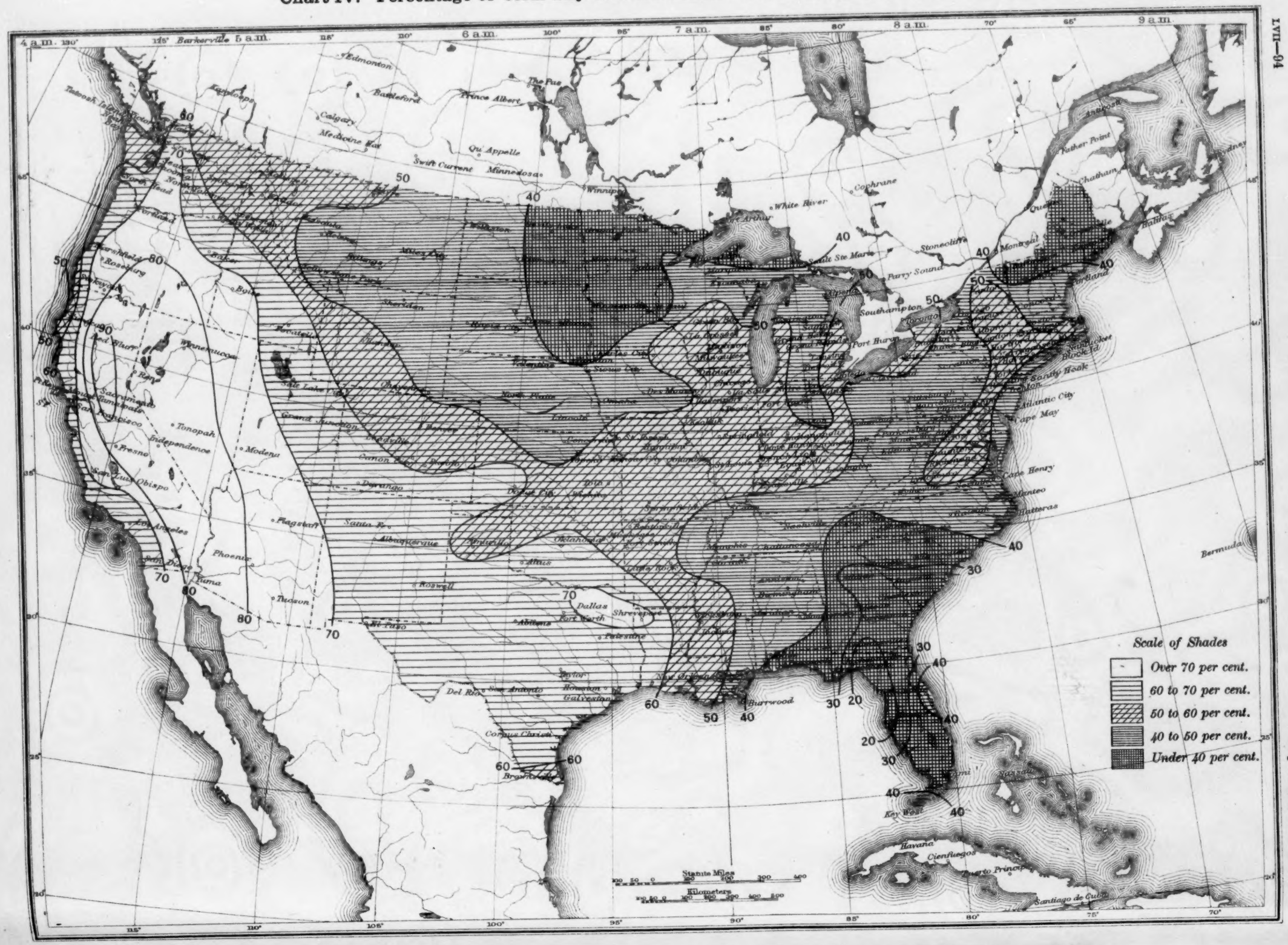
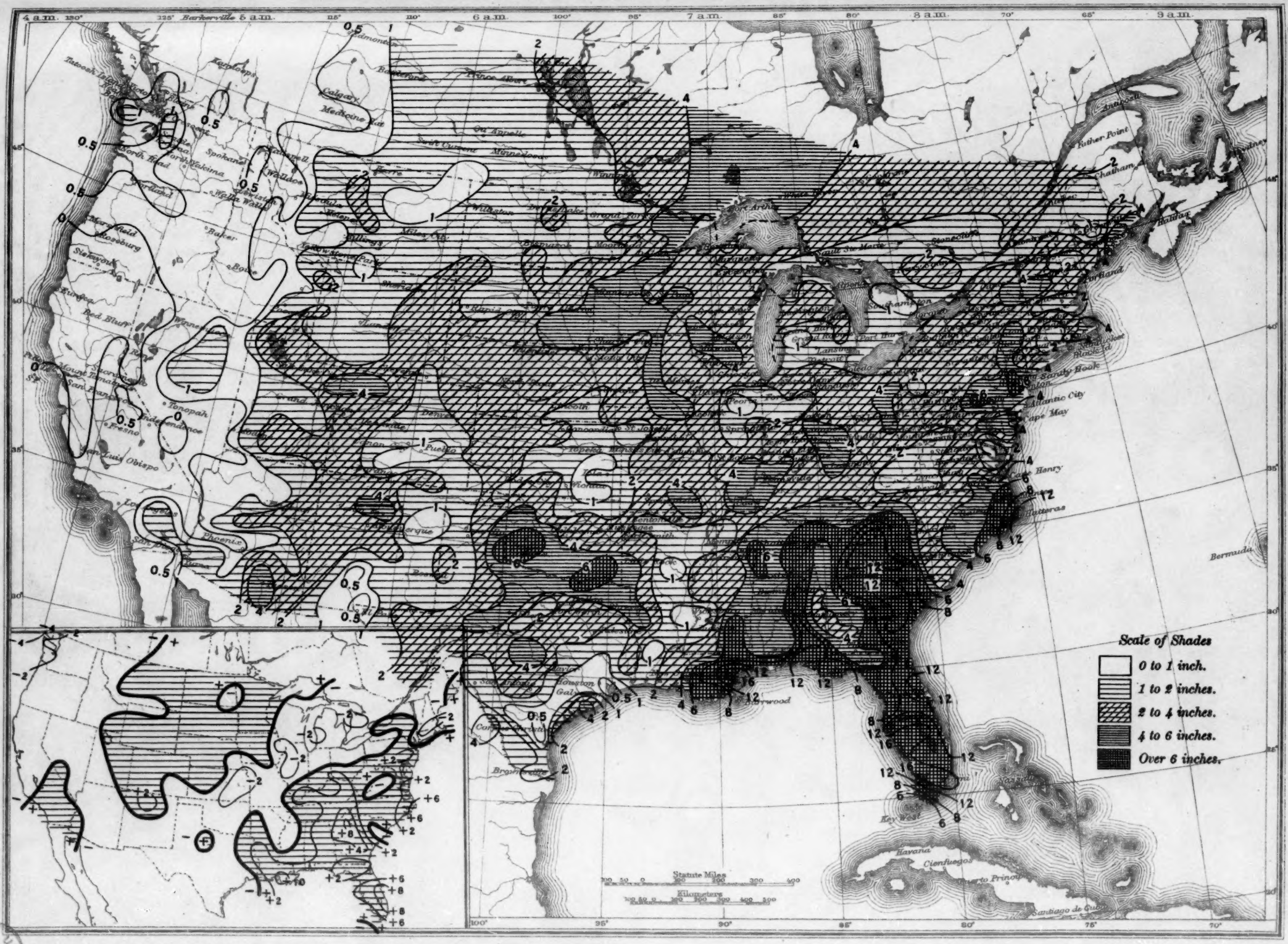


Chart V. Total Precipitation, Inches, September, 1929. (Inset) Departure of Precipitation from Normal

Chart V. Total Precipitation, Inches, September, 1929. (Inset) Departure of Precipitation from Normal



September, 1929. M. W. R.

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Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, September, 1929

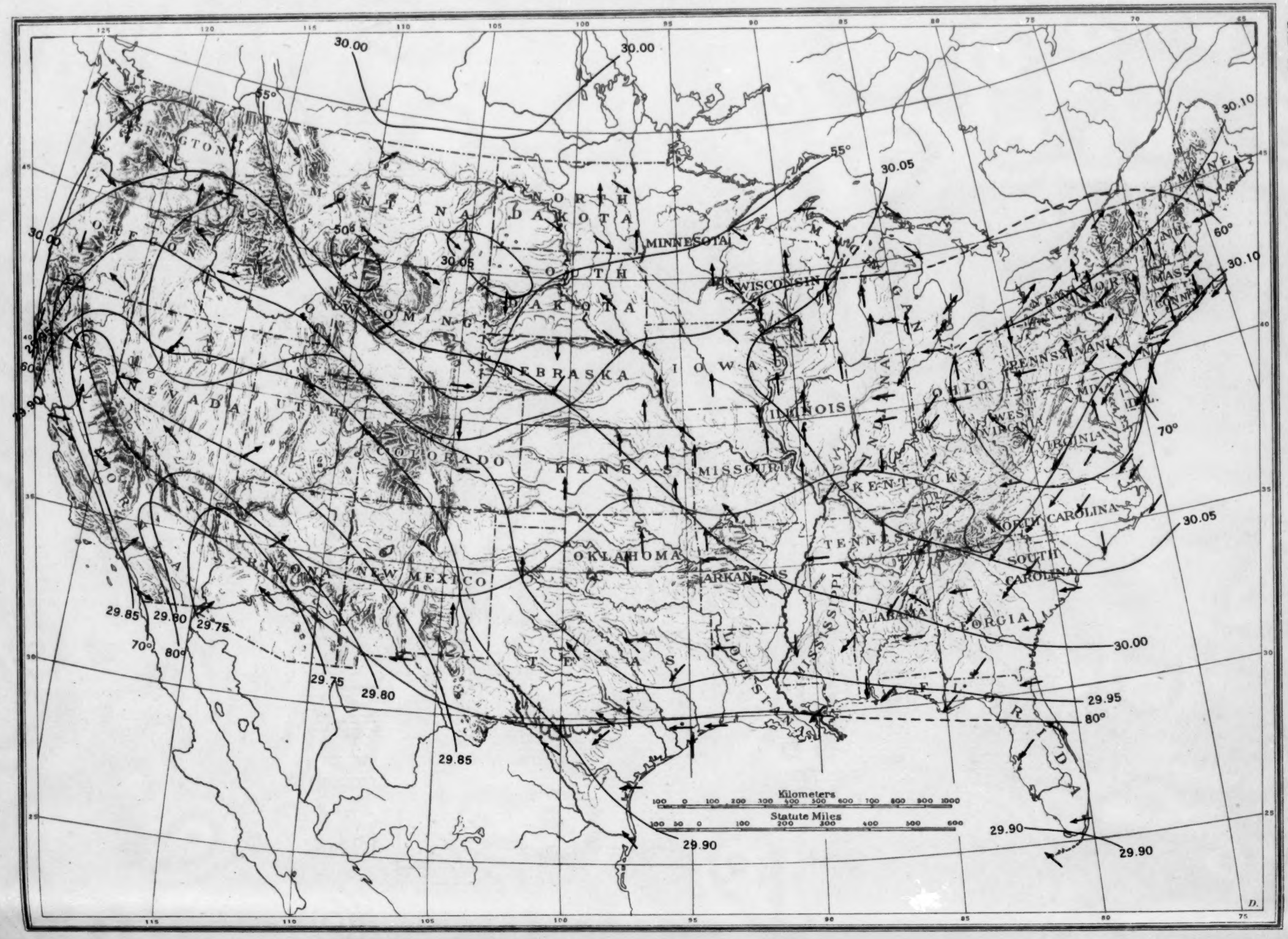


Chart VIII. Weather Map of North Atlantic Ocean, September 23, 1929

(Plotted by F. A. Young)

Chart VIII. Weather Map of North Atlantic Ocean, September 23, 1929

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

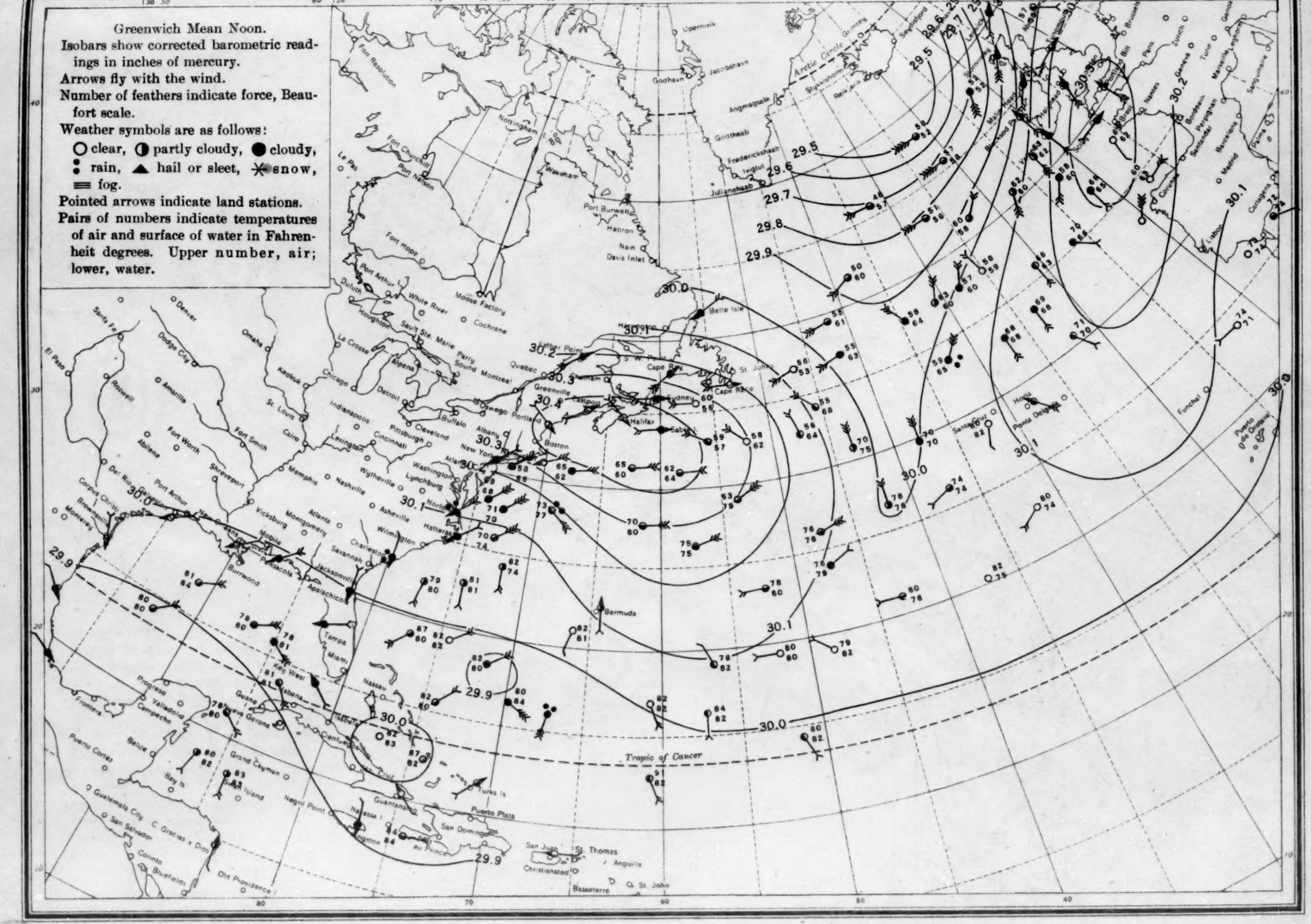


Chart IX. Weather Map of North Atlantic Ocean, September 24, 1929

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ═ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

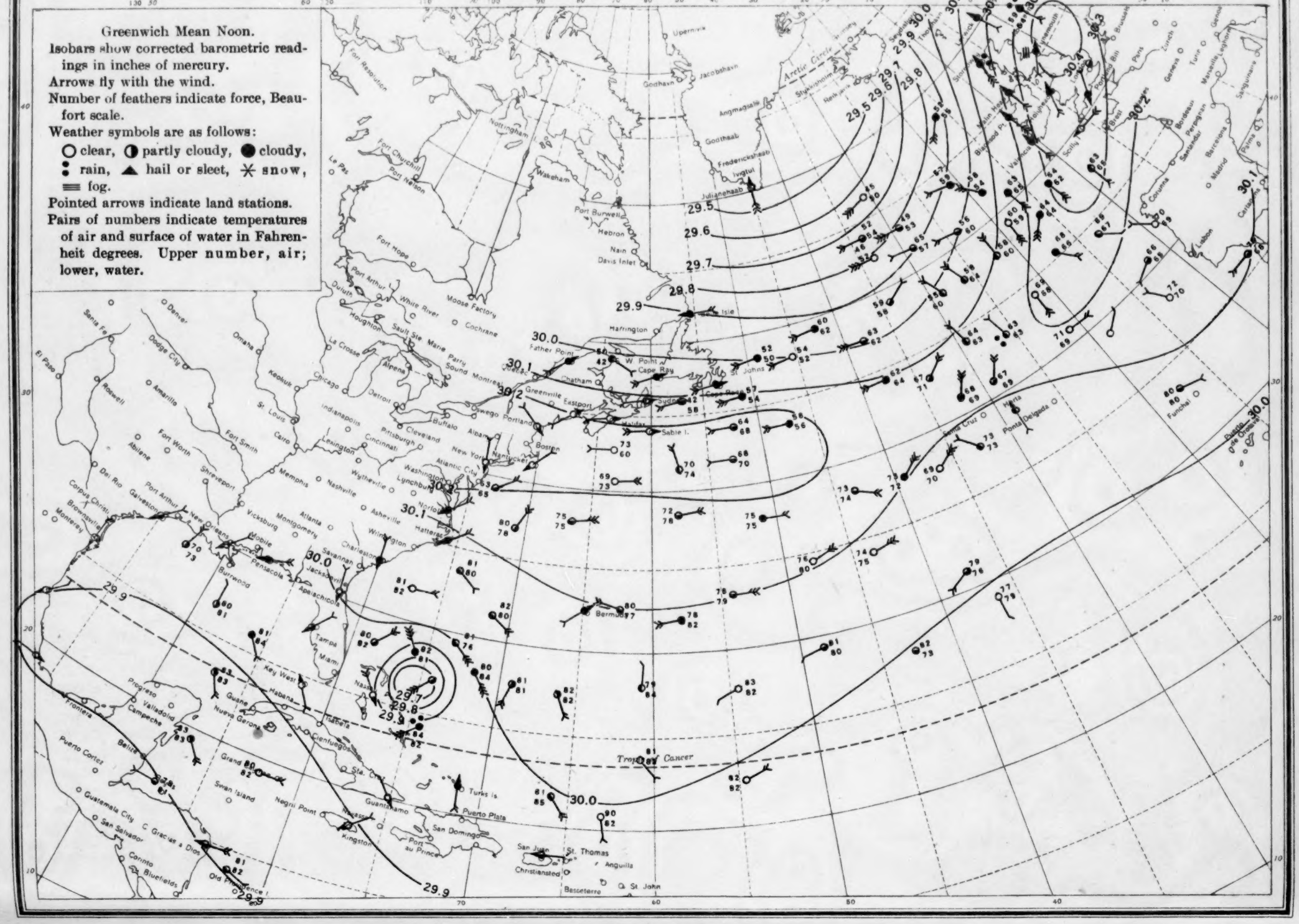


Chart X. Weather Map of North Atlantic Ocean, September 25, 1929

(Plotted by F. A. Young)

Chart X. Weather Map of North Atlantic Ocean, September 25, 1929

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

Chart XI. Weather Map of North Atlantic Ocean, September 26, 1929

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

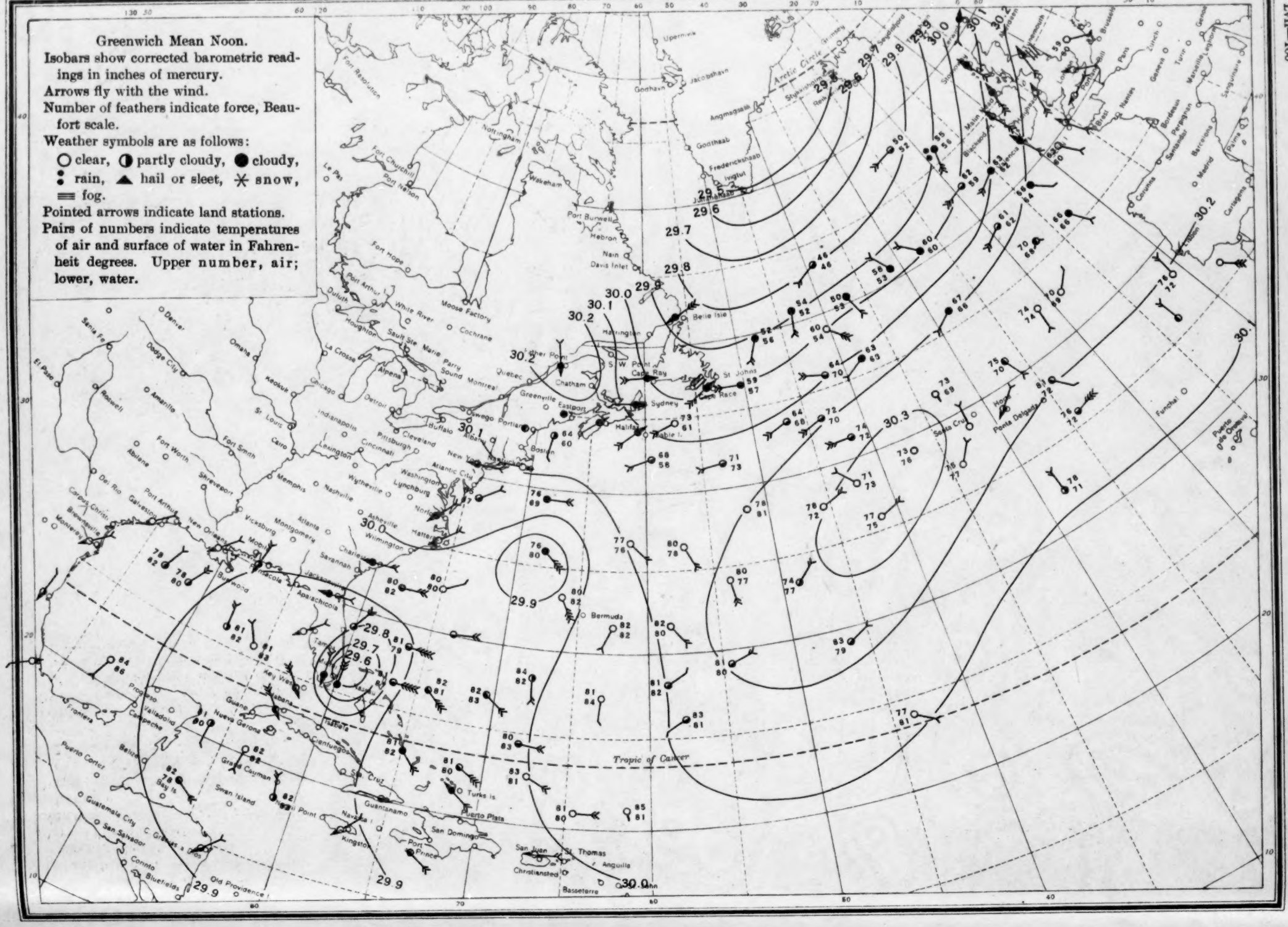
Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.



September, 1929. M. W. R.

Chart XII. Weather Map of North Atlantic Ocean, September 27, 1929

(Plotted by F. A. Young)

Chart XII. Weather Map of North Atlantic Ocean, September 27, 1929

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

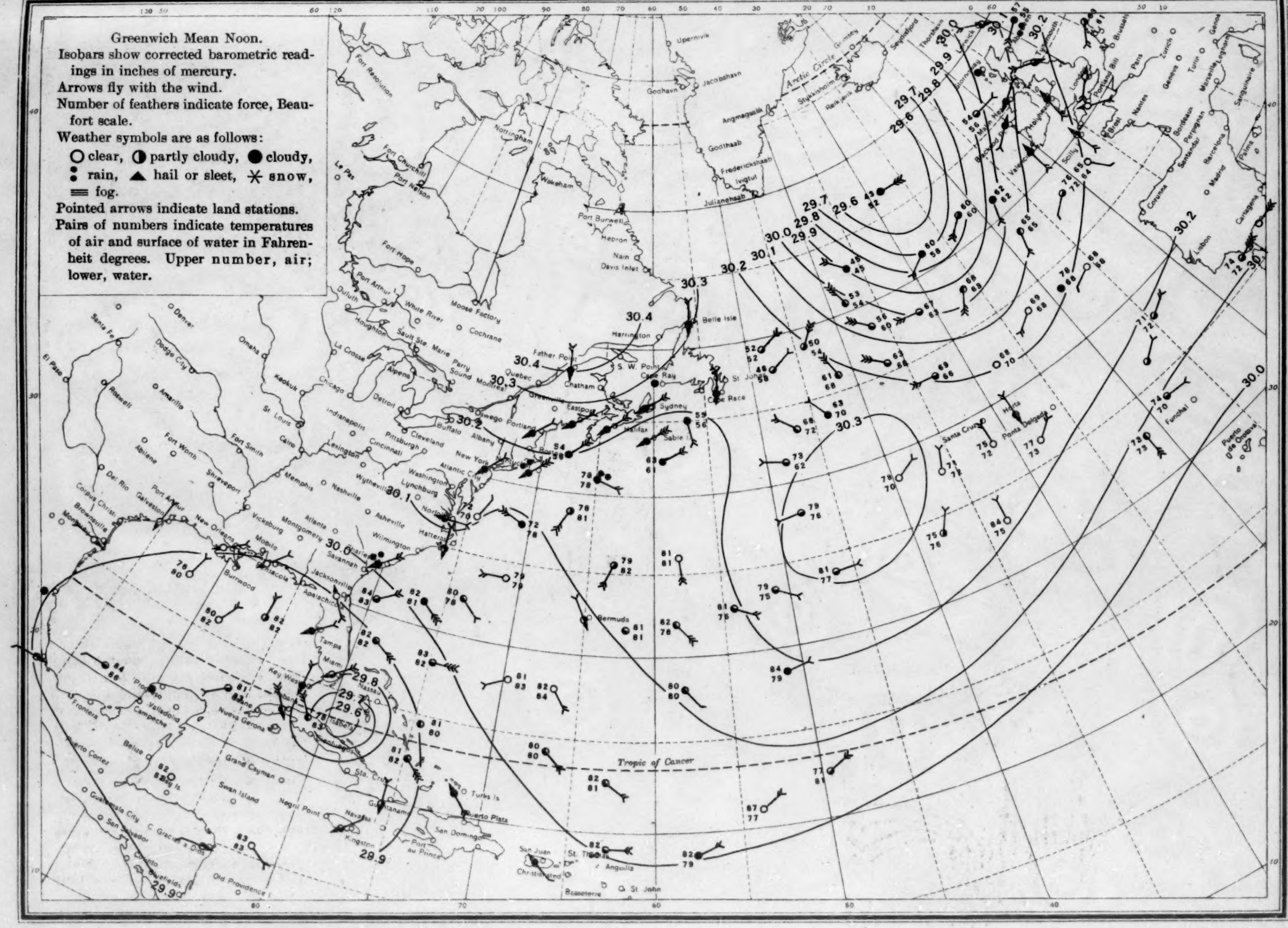


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Chart XIII. Weather Map of North Atlantic Ocean, September 28, 1929

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ═ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

Chart XIV. Weather Map of North Atlantic Ocean, September 29, 1929

(Plotted by F. A. Young)

Chart XIV. Weather Map of North Atlantic Ocean, September 29, 1929

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

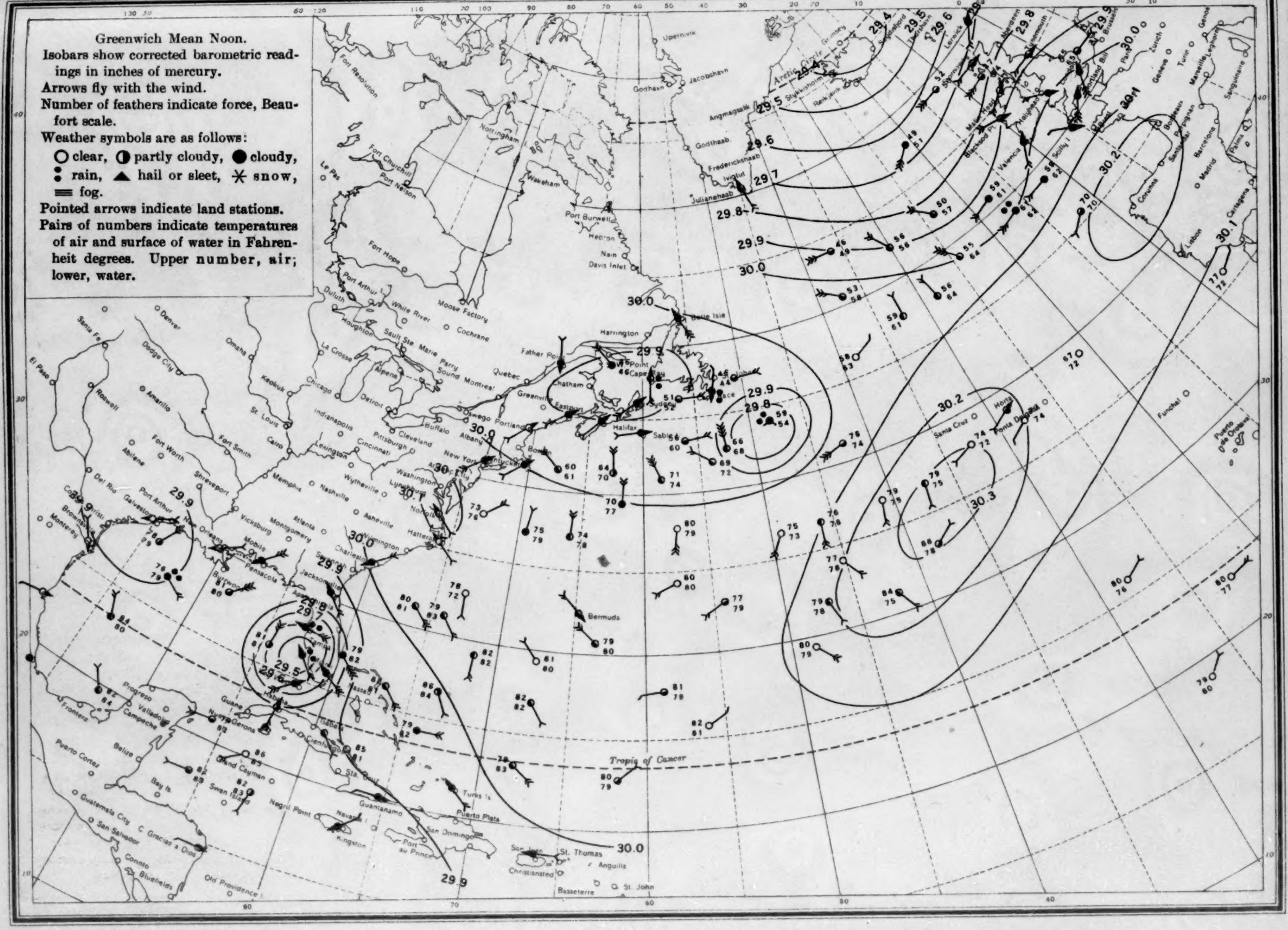

Chart XV. Weather Map of North Atlantic Ocean, September 30, 1929

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.